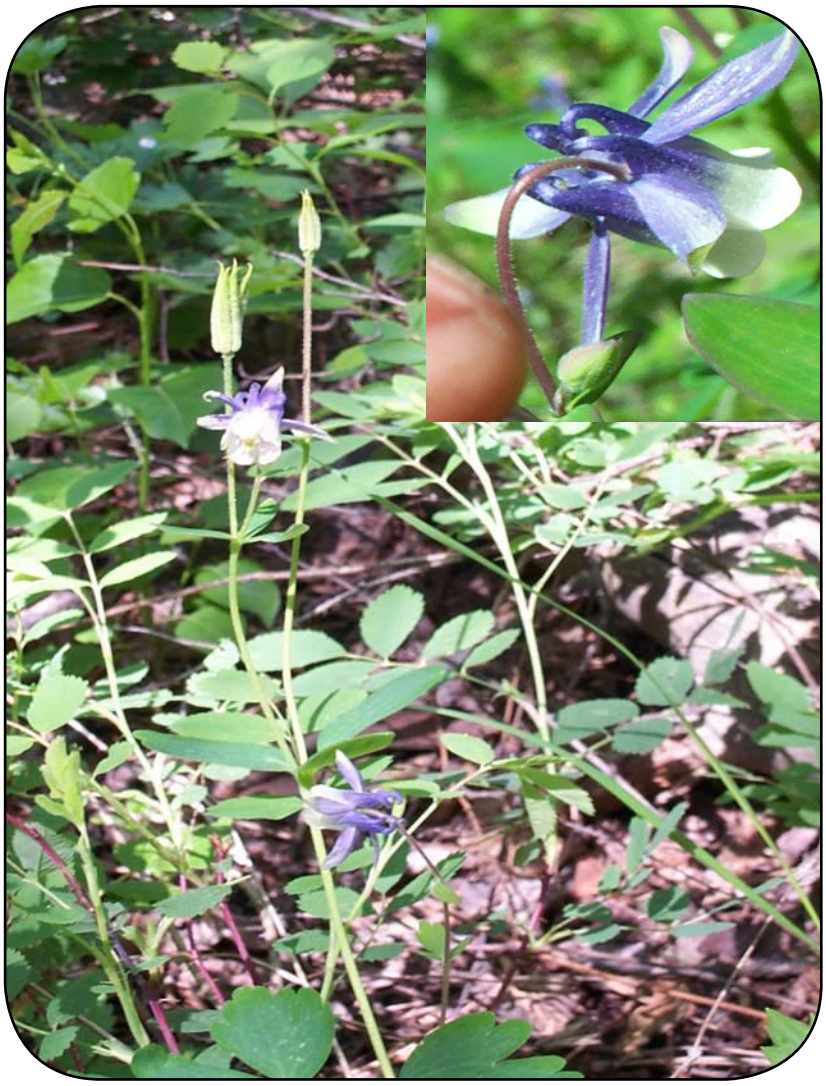
Aquilegia brevistyla Hooker (smallflower columbine): A Technical Conservation Assessment



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Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 14 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates* LLC, an environmental consulting company in Colorado.

COVER PHOTO CREDIT

Aquilegia brevistyla (smallflower columbine). Black Hills National Forest staff, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *AQUILEGIA BREVISTYLA*

Status

Aquilegia brevistyla (smallflower columbine) is known only from Canada and the United States. In U. S. Forest Service (USFS) Region 2, it occurs in South Dakota and Wyoming. The NatureServe Global rank for *A. brevistyla* is G5 (secure), which indicates that it is secure in most of its range although it may be rare in parts of its range, particularly on the periphery. *Aquilegia brevistyla* is ranked S1 (critically imperiled) by the Wyoming Natural Diversity Database and S2 (imperiled) by the Montana Natural Heritage Program. It is unranked by the South Dakota Natural Heritage Program. The Alaska Natural Heritage Program ranks it S3S4 (between vulnerable and apparently secure). In Canada, *A. brevistyla* is ranked S5 (secure) in Alberta and S4 (apparently secure) in British Columbia, Manitoba, Ontario and Saskatchewan. It has been reported but remains unranked in the Northwest Territories and Yukon Territory. Although reported from Minnesota and Quebec, it is unlikely to occur in either area. Region 1 of the USDA Forest Service has designated *A. brevistyla* as a sensitive species, and the Montana Bureau of Land Management lists it as a sensitive species. *Aquilegia brevistyla* was listed as a sensitive species by Region 2 in 2003, but removed from the sensitive species list in 2005.

Primary Threats

The most immediate and potential threat to *Aquilegia brevistyla* appears to be habitat loss. Anthropogenic causes of habitat loss include recreation activities, livestock grazing, extraction of natural resources (e.g. minerals, oil, natural gas, and timber), fire and/or fire-suppression and urbanization and rural residential development. Modification of hydrologic conditions poses a potential threat in some areas. Anthropogenic activities and natural processes result in disturbance that threatens occurrences and species habitat. Invasive, non-native plant species may threaten some occurrences by directly competing with *A. brevistyla* for resources and also contributing to habitat degradation. Houndstongue (*Cynoglossum officinale*) and Canada thistle (*Cirsium arvense*) are at present only sparsely distributed within a few occurrences in the Black Hills, but their presence signals a threat from invasive non-native plant species. The role of cross-pollination in *A. brevistyla* population maintenance is not documented, but over the long term the species may be vulnerable to changes in pollinator assemblage or declines in pollinator abundance. While most of these factors are potential threats rangewide, oil and natural gas development are currently perceived as threats only to occurrences in Canada, Alaska, and Montana. With its showy flowers, *A. brevistyla* is vulnerable to overcollection, but this is not considered a significant threat on NFS lands at this time.

Areas of habitat occupied by *Aquilegia brevistyla* on the Black Hills National Forest are managed primarily for livestock grazing, recreation, and timber production. All of these activities have the potential to detrimentally affect *A. brevistyla* habitat but, at the current levels, their impacts are expected to be low or only localized in nature. The consequences of management practices, such as fire suppression, associated with an expanded urban-wildland interface are unknown. As a consequence of urbanization encroaching upon natural habitat, introduction of horticultural varieties of *A. brevistyla* and other *Aquilegia* species may compromise the genetic integrity of natural populations. Varieties and other *Aquilegia* species can hybridize with local populations and may cause genetic dilution. Like all plants, *A. brevistyla* occurrences are vulnerable to environmental stochasticity and natural catastrophes. Warmer temperatures associated with global climate change are a threat to all species that are restricted to high elevations and northern latitudes. Demographic and genetic stochasticities are also potential threats and it is likely that small and disjunct *A. brevistyla* occurrences, such as those in Montana and the Black Hills, are the most vulnerable.

Primary Conservation Elements, Management Implications and Considerations

An important element of *Aquilegia brevistyla* conservation is the need for definitive and correct identification of plants. Other species of *Aquilegia* have been frequently mistaken for *A. brevistyla*. In addition, there is the potential for hybridization among *Aquilegia* species within its range. *Aquilegia brevistyla* has a very restricted distribution in Montana, Wyoming, and South Dakota, as it is confirmed extant only in Judith Basin County, Montana, and the Black Hills region of Wyoming and South Dakota. Despite targeted searches of historic sites in Montana, Wyoming, and South Dakota, *A. brevistyla* has not been relocated. The extirpation of disjunct occurrences of *A. brevistyla* in the

contiguous United States may lead to a significant loss of genetic diversity because in small populations of *Aquilegia* species that are completely isolated, genes may become fixed through a process of local adaptation. *Aquilegia brevistyla* was recently dropped from the USDA Forest Service Region 2 sensitive species list because recent surveys in the Black Hills indicated that it is more common and colonizes a wider range of habitat conditions than was previously thought.

By extrapolation from other *Aquilegia* species, *A. brevistyla* is likely to be a short-lived perennial with relatively long-lived occurrences in any given locale. However, the longevity of individuals or occurrences is unknown, and its life history is not well understood. It is not clear to what extent *A. brevistyla* occurrences are subject to temporal fluctuations in range and size. If *A. brevistyla* experiences significant mortality and recruitment events at infrequent intervals against a background of low recruitment and mortality levels, systematic observations over a long time period may result in different conclusions than observations made over only a few consecutive years. Lacking sensitive species status, *A. brevistyla* may be overlooked in Region 2 because current management of the species appears to be subject to an individual land manager's personal knowledge. The continuity of management concern for *A. brevistyla* in the case of staff turnover is not assured.

Wide temporal fluctuations in the size of plant populations are not uncommon and may be due to many factors, including the intrinsic biology of the taxon, cyclical pest or environmental events, or land management practices. The large number of *Aquilegia brevistyla* observations made in the Black Hills National Forest between 2001 and 2005 may not represent a true increase in abundance but only an increase in awareness of the species because it was targeted for survey. However, it is also possible that the increased number of plants observed during recent surveys indicates that *A. brevistyla* populations are recovering to levels comparable to those existing before European settlement of the Black Hills region, which resulted in substantial habitat modification. Many practices that were widespread in the late 1800's and early 1900's have since been substantially curtailed or stopped. For example, many mines have closed within the last 50 years. Another example is that since the 1920's, sheep grazing has been substantially reduced and currently does not occur in the Black Hills National Forest. *Aquilegia* species are documented as being highly impacted by sheep grazing, which was intensive in the Black Hills in the late 1800's and early 1900's. Since there is very little information on the historic range and abundance of this species, the consequences of changes in management practices and environmental conditions can only be speculated.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Aquilegia brevistyla* (smallflower columbine) is the focus of an assessment because it is a rare species with a limited range in the United States (i.e., parts of Alaska, Montana, Wyoming, and South Dakota). This species is designated as a sensitive species in USFS Region 1, where it is limited to a few occurrences in Montana (USDA Forest Service 2005). Within the USFS, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology and ecology of *Aquilegia brevistyla* throughout its range but with an emphasis on occurrences on land managed by USFS Region 2. Specific information for many locales outside of Region 2, especially in Canada and Alaska, has not been reported. In some cases, such information is unavailable while in others the available information does not apply to occurrences in Region 2. Limited analysis of existing, but unanalyzed, field data has been made for this assessment. For example, information gathered by the Black Hills National Forest within the last five years, especially in 2003 and 2004, has been examined and summarized in this assessment, but this information needs to be more fully analyzed.

Goal

Conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Aquilegia brevistyla*, with specific reference to the geographic and ecological characteristics of Region 2. Although some of the literature relevant to the species originates from field investigations outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *A. brevistyla* in the context of the current environment rather than under historical conditions.

In producing the assessment, peer-reviewed (refereed) literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Aquilegia brevistyla* may have been referenced in the assessment, but an effort was made to consider all relevant documents. The assessment emphasizes peer-reviewed literature because that is the accepted standard in science. Some non-refereed literature was used in the assessment, however, when information was unavailable elsewhere.

Occurrence data were compiled from the Wyoming Natural Diversity Database (2004), the Montana Natural Heritage Program (2004), field survey forms from the Black Hills National Forest (courtesy Cynthia Buckert and Beth Burkhart, Black Hills National Forest), University of Alaska Museum (ALA), Augustana College Herbarium (AUG), Black Hills State University Herbarium (BHSC), Canadian Museum of Nature (CAN), California State University at Chico (CHSC), University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), Vascular Plant Herbarium of Agriculture and Agri-Food Canada (DAO), Dakota Wesleyan University Herbarium (DWU), Montana State University Herbarium (MONT), University of Montana Herbarium (MONTU), Rocky Mountain Research Station Herbarium (MRC), New York Botanical Garden Herbarium (NY), The Fowler Herbarium of Queen's University (QK), Rocky Mountain Herbarium (RM), South Dakota Herbarium, University of South Dakota (SDU), Great Lakes Forestry Centre Herbarium, Canadian Forest Service (SSMF), Green Plant Herbarium of the Royal Ontario

Museum (TRT), University of British Columbia (UBC) and from the literature (Munz 1946, Cody 1996, Cody et al. 1998, Marriott 1989, Racine et al. 2001). Herbaria acronyms are in accordance with Holmgren and Holmgren (1998). All occurrence data that are not accompanied by herbarium specimens have to be regarded with some skepticism because of the possibility of misidentification. Hybrids have been observed in the Lewis and Clark National Forest (Roe 1992), and vegetative plants are particularly susceptible to misidentification.

In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology and are reliable sources of information. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a peer-reviewed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., NatureServe network, unpublished USFS field forms, herbarium records) were important in estimating the geographic distribution and population sizes of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher than observations only.

Treatment of Uncertainty

Science is a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. Because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, in the ecological sciences, it is difficult to conduct experiments that produce clean results, as may be observed in certain physical sciences. Therefore, observations, inference, good thinking, and models must often be relied on to guide our understanding of ecological relations. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

One element of uncertainty is the likelihood that other *Aquilegia* species have been mistaken for *A. brevistyla*. *Aquilegia* species can be difficult to differentiate when there are no flowers or fruits present; there are documented instances where mis-identification has occurred. Establishing rarity and vulnerability is also subject to uncertainty and may be difficult. When most information has been collected relatively casually, a common criticism with defining a taxon as rare is that there are extensive unsurveyed areas. There is always the possibility that more occurrences will be discovered with additional surveys, and to some extent this is true for all rare taxa. However, rarity is also relative, and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently in a particular area. In addition, systematic observations over a long time period may result in different conclusions than observations made over only a few consecutive years. For example, Coles (2003) reported on demographic data for an endangered cactus in southwestern Colorado compiled over 20 years. Her data indicate that the cactus experiences both significant mortality and recruitment events at infrequent (typically greater than 10 year) intervals. These events stand out against a background of low recruitment and mortality levels in most years (Coles 2003). Because periods in which high levels of germination occur are rare, a short-term study would have either missed them or, if encountered, arrived at the erroneous conclusion that high levels of germination and recruitment are typical for the cactus.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, Web publication facilitates the revision of assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer-reviewed prior to their release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, employing two recognized

experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

NatureServe and many state natural heritage inventory programs use a system established by The Nature Conservancy to rank taxa at global (G) and subnational (S) levels on a scale of 1 to 5. A ranking of G1 or S1 indicates the greatest vulnerability and of G5 or S5 the most secure (see "Ranks" in the **Definitions** section). These ranks carry no regulatory status. The NatureServe (2004a) global rank for *Aquilegia brevistyla* is G5 (secure), which indicates that it is not vulnerable in most of its range although it may be rare in parts of its range, particularly on the periphery. Typically there are considerably more than 100 occurrences and more than 10,000 individuals rangewide for a taxon to be ranked G5. While *A. brevistyla* appears to be secure on a rangewide basis, its status in the United States is more vulnerable. *Aquilegia brevistyla* is designated critically imperiled (S1) by the Wyoming Natural Diversity Database (2005), and imperiled (S2) by the Montana Natural Heritage Program (2005). It has been reported but remains unranked in Minnesota and South Dakota (NatureServe 2004a). *Aquilegia brevistyla* is unlikely to occur in Minnesota and reports from this state are likely due to mis-identification (Ownbey and Morley 1991). Whittemore (1997) supports this opinion and reports that all Minnesota specimens that he examined for the Flora of North America project had been mis-identified. In Alaska, the current conservation status of *A. brevistyla* is uncertain. The number of known collections of *A. brevistyla* appears to warrant a rank of vulnerable (S3) (Lipkin personal communication 2003). However, the low potential for habitat disturbance and the excellent condition of the habitat it occupies suggests that a ranking of apparently secure (S4) might be more appropriate (Lipkin personal communication 2003).

Aquilegia brevistyla is designated a sensitive species by USFS Region 1 (USDA Forest Service 2005) and the U.S. Bureau of Land Management (BLM) in Montana (Montana Natural Heritage Program 2004). USFS Region 2 designated *A. brevistyla* a sensitive species in 2003 (USDA Forest Service 2003b), but in 2005 it was determined that this species no longer merited sensitive species status since recent surveys in the Black Hills indicated that it is more common and colonizes a wider range of habitat conditions than was previously thought (Kratz 2005). Previous concern was largely due to low abundance of the species and an inferred downward trend in its riparian habitat (Kratz 2005). However, *A. brevistyla* is not restricted to riparian habitats in the Black Hills and is often found in mesic sites in conifer and hardwood forests (Kratz 2005).

In Canada, *Aquilegia brevistyla* is ranked secure (S5) in Alberta (Alberta Natural Heritage Information Centre 2002) and apparently secure (S4) in British Columbia, Manitoba, Ontario, and Saskatchewan (Saskatchewan Conservation Data Center 2003, British Columbia Conservation Data Center 2004, NatureServe 2004a). The Ontario Natural Heritage Information Center suggests that there is some uncertainty with the provincial rank by tagging *A. brevistyla* as "?S3S4," which means that it may be more vulnerable than S4 but the exact degree of vulnerability is unknown (Ontario Natural Heritage Information Center 2004). *Aquilegia brevistyla* has also been reported from Quebec, Northwest Territories, and Yukon Territory. However no verifiable records to support its existence in Quebec could be obtained for this report (Scoggan 1950a, Gleason and Cronquist 1991, Waterway personal communication 2005). In the most recent treatment of the genus *Aquilegia*, Quebec is excluded from the range of *A. brevistyla* (Whittemore 1997).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Aquilegia brevistyla has been reported from National Forest System lands in Wyoming and South Dakota (Region 2) and in Montana (Region 1). This species was added to the Region 2 sensitive species list in 2003 (USDA Forest Service 2003b). The goal of the USFS sensitive designation is to minimize impacts associated with anthropogenic activities on the species. A sensitive designation requires that prior to any major federal project on National Forest System land, potential impacts to the taxon must be evaluated through a biological evaluation process (USDA Forest Service 1994). If the expected impacts are determined to likely cause substantial harm to occurrences or the total population, the project may be redesigned or mitigation measures may be considered. The management of *A. brevistyla* was addressed in the Black Hills National Forest Phase II Amendment of the Draft Environmental Impact Statement (USDA Forest Service 2004a). Targeted surveys for the taxon

were conducted between 2003 and 2005, and these resulted in the discovery of approximately 65 locations distributed over approximately 19 watersheds within the Black Hills National Forest (Burkhart et al. personal communication 2006). As of 2005, *A. brevistyla* is no longer listed as a sensitive species in Region 2 (USDA Forest Service 2005). Although the species will no longer be given special consideration in management planning or implementation, its presence will be noted if encountered during inventory or monitoring of other taxa (Burkhart et al. personal communication 2006). At the present time, the National Forest System lands in Region 2 on which *A. brevistyla* occurs are managed primarily for grazing, logging, and/or recreation (USDA Forest Service 2004a). Grazing allotments in which it occurs are currently active.

Aquilegia brevistyla is designated as a sensitive species by USFS Region 1 in Montana, where it has been found most frequently on the Lewis and Clark National Forest. Surveys were conducted on this forest between 1989 and 1997 for a number of sensitive plant species, including *A. brevistyla*, within identified project areas (Murphy personal communication 2005). Baseline inventory data were collected for *A. brevistyla* in 1991 (Roe 1992). In most cases, *A. brevistyla* occurrences that were found between 1992 and 1996 were extensions of known occurrences. However, several new occurrences were found in 1996 (**Table 1**). Once occurrences were located, they were flagged and identified on sale area/activity maps (Murphy personal communication 2005). Since 1996, major *A. brevistyla* population centers have been avoided as much as possible during ground-disturbing activities (Murphy personal communication 2005). The timber sale administration group at the Lewis and Clark National Forest searches for sensitive species prior to timber sales and generally avoids occurrences that they locate (Murphy personal communication 2005). Some plants along the periphery of certain occurrences may have been affected during some projects, but the overall *A. brevistyla* population on the Lewis and Clark National Forest was deemed to be unaffected (Murphy personal communication 2005). An amendment to the Lewis and Clark National Forest Plan was adopted on October 12, 1993, adding management goals, objectives, standards, and monitoring items for sensitive plant species, including *A. brevistyla* specifically (Murphy personal communication 2005). No monitoring or targeted survey programs have been conducted for *A. brevistyla* since 1997. No consequences of the conservation policies initiated in the early 1990's or of the active management practices implemented prior to 1997 have been documented.

In 1967, one *Aquilegia brevistyla* occurrence was reported along the Boulder River in Montana. From the location information, it is not clear if the specimen was actually collected from the Gallatin National Forest (Region 1) or from private land. *Aquilegia brevistyla* has not been found in the area since this original collection despite subsequent surveys (Mathews 1989, Montana Natural Heritage Program 2004).

The BLM lists *Aquilegia brevistyla* as a sensitive species in Montana (Montana Natural Heritage Program 2004) but not in Wyoming (USDI Bureau of Land Management 2002). The objectives of the BLM special status species policy are: "To conserve listed species and the ecosystems on which they depend" and "to ensure that actions requiring authorization or approval by the Bureau of Land Management are consistent with the conservation needs of special status species and do not contribute to the need to list any special status species, either under provisions of the ESA or other provisions of this policy" (USDI Bureau of Land Management 2001).

Aquilegia brevistyla may occur on land managed by the National Park Service (NPS) in South Dakota; an occurrence was reported in 1924 from Wind Cave National Park in the southwest corner of the state. National parks are managed by the NPS "...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (National Park Service Organic Act, 16 U.S.C.1.). The "Organic Act" of August 25, 1916, states that the NPS "shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Logging, mining, and other activities allowed in national forests are usually prohibited in national parks (Environmental Media Services 2001). Livestock grazing may be permitted in national parks, as long as such use is not detrimental to the primary purpose for which the park, monument, or reservation was created (National Park Service undated).

Table 1. Information on *Aquilegia brevistyla* occurrences in Montana (USDA Forest Service Region 1), including county, location, land management/ownership, date of observation, abundance, habitat, and other comments recorded for each occurrence record. The botanical or common names of associated plant species have been reported as described by the field observer.

Arbitrary number	County	Location	Land management/ ownership	Date(s) of observation	Abundance	Habitat	Other comments	Source[1]
1	Sweet Grass	20 miles above the town of McLeod along the Boulder River. Note: NOT FOUND since 1967. Over approximately the last three decades searches made on parts of 99 sections where suitable habitat occurred.	Gallatin National Forest and/or possibly private land	4 Jul 1967	No information	No information.	Specimen in fruit but identification is questionable. R. Dorn commented "Probably *A. coerulea* James"; A. Plantenberg 1983 commented: "no"; S. Shelly commented "Floral measurements inconclusive." S. Matthews comments: "plant pressed such that flowers cannot be properly measured." Surveys in 28-30 July 1989, by S. Matthews, did not find *Aquilegia brevistyla* or *A. coerula*.	*L. Thornton #s.n.* 1967. MONT. Montana Natural Heritage Program (2004)
2	Judith Basin	Little Belt Mountains; Population is approximately 0.1 mile up Smith Creek from the confluence with the South Fork Judith River.	Lewis and Clark National Forest	18 Jul 1991	Two plants, past flower	On mesic limey shale outcrop in partial shade of a lower slope. *Picea englemannii/Linnaea borealis*, with *Thalictrum occidentale*, *Athyrium filix-femina*, *Galium triflorum*, *Ribes lacustre*, *Acer glabrum*, Feather mosses and *Calypso bulbosa*.	Plants were identified on the basis of short-styled capsules; collections need to be made in flower for positive identification.	Montana Natural Heritage Program (2004)
3	Judith Basin	Little Belt Mountains. About 16 miles southwest of Utica, South Fork of Judith River (Dry Pole Canyon).	Lewis and Clark National Forest	1956, 1 Jul 1991	Approximately 45 plants in two main subpopulations and several scattered plants	Ecotonal to *Pseudotsuga menziesii* (13-14" DBH)/*Pinus contorta* forest. Associated with *Fragaria virginiana*, *Galium boreale*, *Potentilla fruticosa*, *Antennaria racemosa*, *Arctostaphylos uva-ursi*, *Smilacina stellata*, *Habenaria viridis* and *Linnaea borealis*. Site is partially shaded by vegetation and partially by its canyon bottom position. Calcareous rocky soils with a thick duff and moss layer; moist site.	Plants further up the Canyon have characteristics intermediate between *Aquilegia brevistyla* and *A. flavescens*. About 0.5 miles beyond last intermediate, all plants showed characteristics of *A. flavescens*.	*A. Lovaas. #s.n.* 1956. *L.S. Roe #442, 1-6* 1991 MONT. Montana Natural Heritage Program (2004)

Table 1 (cont.)

Arbitrary number	County	Location	Land management/ ownership	Date(s) of observation	Abundance	Habitat	Other comments	Source[1]
4	Judith Basin	Little Belt Mountains, High Spring Creek, near the South Fork of Judith River, about 17 miles southwest of Utica.	Lewis and Clark National Forest	2 Jul 1991	100 to 200 plants, scattered	In calcareous soils within and at margins of *Pseudotsuga menziesii* and *Pinus contorta* forest. In Feathermoss with *Clematis columbiana*, *Linnaea borealis*, *Antennaria racemosa*, *Smilacina stellata* and *Potentilla fruticosa*.	No *Aquilegia flavescens* present.	*L.S. Roe #445.* 1991. MONT. Montana Natural Heritage Program (2004)
5	Judith Basin	Little Belt Mountains, Hay Canyon near the South Fork Judith River, approximately 14 miles southwest of Utica.	Lewis and Clark National Forest	3 Jul 1991	800 to 1,000 stems	Plants scattered along canyon bottom and roadside in calcareous, rocky soils. *Pesudotsuga menziesii/Pinus contorta* forest with *Clematis columbiana*, *Linnaea borealis*, *Arctostaphylos uva-ursi*, *Galium boreale*, and *Fragaria virginiana.*	Portions of population in disturbed habitats (roadside gravels).	*L.S. Roe #447.* 1991. MONT. Montana Natural Heritage Program (2004)
6	Judith Basin	Little Belt Mountains. South Fork Judith River, approximately 14 miles southwest of Utica, on bench at side of road.	Lewis and Clark National Forest	9 Aug 1991	25 plants	Canyon bottom, in rocky calcareous soils beneath *Pseudotsuga menziesii* and *Pinus contorta* with *Clematis columbiana*, *Juniperus communis Linnaea borealis*, *and Arnica cordifolia*, *Acer glabrum*, *Arctostaphylos uva-ursi*, and *Goodyera repens*.	Pods (seeds) collected from this site on 9 Aug 1991 and sent to Trinity University, Dept. Biology, San Antonio TX for a genetic study.	Montana Natural Heritage Program (2004)
7	Judith Basin	Little Belt Mountains. South Fork Judith River, approximately 0.5 mile north of Russell Point, on west side of river where a small creek flows into the South Fork.	Lewis and Clark National Forest	2 Jul 1991	Approximately 25 plants	In rocky calcareous soil in shaded location, ground covered by Feathermoss with *Clematis columbiana*, *Linnaea borealis*, *Pseudotsuga menziesii*, and *Juniperus communis*.	Population may contain hybrids. Two collections: One keys easily to *Aquilegia brevistyla*, the second shows characters intermediate between *A. brevistyla* and *A. flavescens*.	*L.S. Roe #466-1,2.* 1991. MONT. Montana Natural Heritage Program (2004)

Table 1 (cont.)

Arbitrary number	County	Location	Land management/ ownership	Date(s) of observation	Abundance	Habitat	Other comments	Source[1]
8	Judith Basin	Little Belt Mountains, approximately 2 miles south of Dry Pole campground. Site is east of South Fork Judith River, along the bottom of the ridge.	Lewis and Clark National Forest	Aug 1991	Several thousand individuals	Semi-open, moist drainage bottoms and lower slopes, limestone bedrock, silty clay loam soil. *Clematis columbiana*, *Linnaea borealis*, *Pseudotsuga menziesii*, , and *Picea englemannii/ Linnaea borealis* habitat types. *Pinus ponderosa*, *Shepherdia canadensis*, *Juniperus communis*, *Spiraea betulifolia*, *Geranium richardsonii*, *Festuca idahoensis*, *Poa spp.*, *Hylocomium splendens*, *Pleurozium schreberi*, *Drepenocldus uncnatus*, *Timmia austriaca*, and *Thuidium abietinum*. Also *Goodyera repens*.	Full flower to past flower. Plants scattered over a large area. Along Burley creek, plants occur alongside old, revegetated roadway accessing a small timber harvest. Noted that: A later survey extended the boundaries of the occurrence.	Montana Natural Heritage Program (2004)
9	Judith Basin	About 12 miles southwest of Windham, along Sage Creek and FS Road #265.	Lewis and Clark National Forest	1990, 1991, 22 Jul 1992	1990: Approximately 2,000 plants in flower and fruit 1991: 750 to 1,000 plants	Ecotone between Englemann spruce/ Douglas fir forest and *Festuca scabrella/Poa pratensis* meadows. Alluvial and colluvial limestone substrate. Associated species: *Linnaea borealis*, *Juniperus communis*, *Arnica cordifolia*, *Arctostaphylos uva-ursi*, *Pyrola secunda*, *Phleum pratense*, and *Festuca scabrella*.	1990: Scattered individuals up Hay Coulee; very distinct blue sepals and short hooked spurs. Population probably extends up Hay Coulee and Sage Creek. About one third of site burned in November 1990. Much of overstory burned in the Fall (November) of 1990. 1991: After fire, plants were still present where the duff did not burn. Subpopulations at and above Hay Coulee along Sage Creek still present, and about half in flower. Plants in adjacent sub population in another section may be gone [extirpated]. A monitoring study was initiated in 1991.	*H.W. Phillips #900629-1*. 1990. MONTU. MONT. MRC. Montana Natural Heritage Program (2004)

Table 1 (cont.)

Arbitrary number	County	Location	Land management/ ownership	Date(s) of observation	Abundance	Habitat	Other comments	Source[1]
10	Judith Basin	Approximately 18 miles southeast of Neihart, approximately 0.5 miles south of Burris Cabin on FS trail #433.	Lewis and Clark National Forest	1990, 2 Jul 1991	1990: A few plants 1991: Approximately 100 plants	Along trail; all forested, about 50 percent canopy closure. Associated species: *Pinus contorta*, *Abies lasiocarpa*, *Pseudotsuga menziesii*, *Thalictrum occidentale*, *Calamagrostis rubescens*, *Aster conspicuus*, *Cypripedium montanum*, *Linnaea borealis*, *Galium boreale*, *Antennaria racemosa*, *Viola canadensis*, and extensive moss cover.	1990: Bloom nearly finished July 4. Verified by D. Fiekd in 1990. Population covers a small area from trail west to creek. 1991: Plants in full bloom on July 2 (wet, cold May and June).	Montana Natural Heritage Program (2004)
11	Judith Basin	From Judith Guard Station, upriver along the middle fork Judith River on north side to flume diversion. Population starts there and continues upstream in river bottom. 1996: Subpopulation approximately 11 miles southwest of Utica to FS road 487. Site is east of road to Judith Ranger Station of Road 822.	Lewis and Clark National Forest	25 Jun 1995, 2 Jul 1996	1995: 100 plants 1996: 200 to 300 individuals in five subpopulations	1995: Moist, shaded river bottom with alluvial soil. Associated species: *Picea englemanii*, *Linnaea borealis*, *Viola canadensis*, *Betula occidentalis*, and *Hylocomium splendens*. 1996: Partly shaded, moist draw bottom and adjacent toe slope. Dominant plant species include: *Pseudotsuga menziesii*, *Symphoricarpos albus*, *Picea englemanii*, *Smilacina stellata. Additional plant associates include: Acer glabrum*, *Disporum trachycarpum*, *Symphoricarpos albus*, *Spiraea betulifolia*, *Allium brevistylum*, *Mertensia oblongifolia*, *Aster ciliolatus*, *Galium triflorum*, *Hylocomium splendens* (Feather moss), *Rosa acicularis*, *Thalictrum occidentale*, *Poa nervosa*, and *Carex sprengelii*.	1995: Disturbance by livestock. Population likely extends upriver. Further study needed. Also observed by J. Maloof and V. Bloodsworth. 1996: All in early fruit. Evidence of seed dispersal and establishment include seed production; seedlings established in deep organic layer. Also observed by S. Markow.	Montana Natural Heritage Program (2004)

Table 1 (concluded).

Arbitrary number	County	Location	Land management/ ownership	Date(s) of observation	Abundance	Habitat	Other comments	Source[1]
12	Judith Basin	Approximately 15 miles southwest of Utica. Population extends from Bear Gulch, down Yogo Creek, and up Sawmill Gulch. Occurrence over parts of eight contiguous sections.	Lewis and Clark National Forest	15 Jul 1993, 30 Jun 1995	1993: 2,000 plants, two subpopulations (east and west forks of Bear Gulch) occurring as individuals in small groups. 1995: 1,000 plants in five subpopulations	Moist and moderately dry, partial shade bottom toeslope and moist shaded cold air drainages. *Pseudotsuga menziesii/Juncus compressus* habitat type. Limestone soil. Associated species: *Pseudotsuga menziesii*, *Picea*, *Pinus contorta*, *Juniperus communis*, *Clematis columbiana*, *Arnica cordifolia*, *Fragaria virginiana*, *Goodyera repens*, *galium*, *Geranium*, *Zigadenus valdio*, *Pyrola sp.*, *Smilacina stellata*, *Linnaea borealis*, *Symphoricarpos albus*, *Thalictrum occidentale*, *Valeriana dioica*, *Berberis repens*, *Pinus ponderosa*, *Physocarpus malvaceus*, *Shepherdia canadensis*, *Rosa acicularis*, *Arctostaphylos uva-ursi*, *Hedysarum sulphurescens*, *Hylocomium splendens*, and *Linnaea borealis*.	1993: In flower and fruit. Evidence of seed dispersal and establishment. Expansion of main population and two new subpopulations observed in 1994. Main population with 300 to 400 fruiting plants; one subpopulation consisting of three fruiting plants; other subpopulation consisting of about 200 plants, half seedling, half fruiting. 1995: 20 percent in flower. Evidence of seed production noted. Much more abundant in east fork bottoms and toeslopes, including logged area. Sparse in west fork. Disturbance by insects and grazing; logging and road construction in area. Timber harvest scheduled but populations flagged and to be excluded from harvest activity.	Montana Natural Heritage Program (2004)

[1]Herbarium abbreviations (Holmgren and Holmgren 1998):

MONT: Montana State University, Bozeman, MT

MONTU: University of Montana, Missoula, MT

MRC: Rocky Mountain Research Station, Missoula, MT

The Alaska Natural Heritage Program and the Canadian Conservation Data Centers do not track *Aquilegia brevistyla* (Donovan personal communication 2003, Lipkin personal communication 2003, Rintoul personal communication 2003). In these northern regions, *A. brevistyla* is not viewed as needing special management because, although uncommon on a province-wide basis, there are areas where it is locally abundant. In Canada, several occurrences are in national parks and preserves, such as the Prince Albert National Park close to the center of Saskatchewan, and Riding Mountain National Park on the Manitoba Escarpment in south-central Manitoba (**Table 2**; Information Center for the Environment 2003, Innvista undated). National parks in Canada are managed for their scenic or historical significance (Canada National Parks Act 2000) and may provide protection to the occurrences of sensitive plants growing within them. These parks and areas are oriented toward recreation; logging, mining, and other such development activities are usually prohibited (Canada National Parks Act 2000). The wilderness areas in which *A. brevistyla* occurs in Canada also prohibit mountain bikes and horses, but livestock grazing may be permitted on a site-specific basis. *Aquilegia brevistyla* is also in the Weaselhead Natural Area within the city limits of Calgary, Alberta. Hikers may inadvertently trample plants at this site, but otherwise it is protected by city bylaws (Yaki undated). An occurrence has also been reported from the Duck Mountain Provincial Park in Saskatchewan (Ladyka 2002), a recreation area where similar protections are likely to apply.

The available information suggests that *Aquilegia brevistyla* seeds have not been banked for conservation purposes. "Seeds of Success" is an interagency seed-banking program coordinated through the Plant Conservation Alliance with the goal to increase the number of species and the amount of native seed that is available for use in stabilizing, rehabilitating, and restoring lands in the United States (Plant Conservation Alliance 2005). *Aquilegia brevistyla* seed has not been targeted for collection by this program. This might be because *A. brevistyla* does not appear to fit the collection criteria:

- native species of known forage or browse value, especially those plant species important to declining or endangered wildlife species
- widespread regional endemic plant species (i.e., species that are very common where they occur but have a distribution that is limited to a small area or only one ecoregion)
- native wild relatives of cultivated species or economically important native species
- native species with significance to Native American Tribes
- monotypic native species (i.e., species where there is only one species in a genus or one genus in the family in the U.S. flora)
- native species closely related to rare species not collected in this project
- native species closely related to non-native invasive weed species

Table 2. Canadian national parks and reserves where *Aquilegia brevistyla* has been reported (The Information Center for the Environment 2003); see also **Table 4**.

Protected Area:
Banff National Park
Elk Island National Park
Jasper National Park
Kluane National Park and Reserve
Kootenay National Park
Nahanni National Park Reserve
Prince Albert National Park
Riding Mountain Biosphere Reserve
Wapusk National Park
Wood Buffalo National Park

- native species that are important to declining pollinators

- 'flagship' or well-known species that the public recognizes (e.g., native state flowers and trees).

The second criterion in this list may partially apply to *Aquilegia brevistyla* in the contiguous United States.

Seed samples of *Aquilegia canadensis*, which also occurs in the Black Hills, are held by Millennium Seed Bank Kew (Plant Conservation Alliance 2005). This taxon has many of the same ecological and biological characters of *A. brevistyla*, but it fits several of the conditions more clearly; for example, it has documented significance to Native American Tribes (Moerman 1998).

Biology and Ecology

Classification and description

Systematics and synonymy

Aquilegia is a member of the Ranunculaceae, also known as the crowfoot or buttercup family (Whittemore 1997). There are approximately 70 species of *Aquilegia* (Whittemore 1997), and the majority of them can interbreed. The barriers that separate the species have been described as geographic rather than cytogenetic (Munz 1946, Taylor 1967). Notwithstanding the inter-fertility between species, there appears to be considerable taxonomic integrity maintained by sympatric species (Grant 1952). Little natural hybridization occurred among different species of *Aquilegia* planted together in rows (Anderson and Schafer 1933). This segregation is probably at least partially explained by effective isolation mechanisms, including differences in flowering time, flower structure, and consequent pollinator preferences.

Payson (1918) divided *Aquilegia* into three intrageneric divisions: *Crytoplectrae*, *Rhodanthae*, and *Macroplectrae*. He considered *A. brevistyla* to belong to the Old World columbines and placed it, along with *A. saximontana* and *A. laramiensis*, in *Crytoplectrae* (Payson 1918). When Munz (1946) reviewed the early attempts to form intrageneric divisions, he concluded that the shortcoming of most groupings was that there was often considerable overlap, especially if Asiatic species were included in the analysis. Munz (1946) also concluded that *A. brevistyla* is more closely related to Asiatic rather than to American species, with the possible exceptions of *A. saximontana* and *A. laramiensis*, both of which have short stems and flowers among the leaves. *Aquilegia brevistyla* and *A. laramiensis* are also similar in that they both have short styles, included rather than exerted stamens, and short spurs. Taylor (1967) placed *A. brevistyla* in its own complex of just the one species, but he omitted *A. laramiensis* from his analyses. Taylor (1967) also noted that *A. brevistyla* shares several characteristics with the two Eurasian species *A. sibirica* and *A. flabellata*: short spurs, included stamens, blue and white flower color, short styles, and structurally similar follicles. However, on the basis of inter-specific cross-pollination success and the resulting hybrid's pollen fertility, the affinities of *A. brevistyla* were shown to lie within the American complexes (Taylor 1967). Whittemore (1997) did not use intrageneric divisions in his recent treatment of *Aquilegia* for the Flora of North America.

No synonyms for *Aquilegia brevistyla* are currently recognized (Kartesz 1994, Whittemore 1997). In Munz (1946), synonyms of *A. brevistyla* included *A. vulgaris* var. *brevistyla* from Gray (1862), *A. brevistyla* var. *vera* from Brühl (1892), and *A. brevistyla* var. *altior* from Rapaics (1909). As Rydberg (1896) pointed out, mistakes in identification between *A. brevistyla* and *A. saximontana* in the late 1800's and early 1900's may have led to historical inconsistencies in the literature when describing the range, morphology, and synonyms of *A. brevistyla*. A photograph and collection details of the isotype of *A. vulgaris* var. *brevistyla* collected by C.C. Parry in 1841 "from the headwaters of Clear Creek and the alpine ridges east of Middle Park, Colorado territory" are on the New York Botanical Garden Herbarium Internet site (2003). P.A. Munz in the early 1940's annotated this specimen as *A. saximontana*. Rapaics (1909) reviewed the genus *Aquilegia* and identified two varieties of *A. brevistyla*: a dwarf type, *A. brevistyla* var. *patula*, and a "stronger" type, *A. brevistyla* var. *altior*. The dwarf variety may have referred to *A. saximontana*, which was not mentioned in his review.

The derivation of the name *Aquilegia* is debatable. It may come from the Latin *aqua*, meaning water, and *legere*, meaning to collect, because of either the wet habitat favored by some species or the quantity of liquid nectar that collects in the spurs of the flowers (Whittemore 1997). Alternatively, the name may come from the Latin *aquila*, meaning eagle, because of the claw-shaped nectaries (Gledhill 1992). The epithet *brevistyla* is derived from the Latin *brevis*, meaning short, and *stylus*, referring to the style.

History of species

Historic literature indicates that a Dr. Richardson first collected *Aquilegia brevistyla* in the early nineteenth century during the First Expedition to the North Pole (1819-1822) and tentatively referred to it as *A. vulgaris* (Hooker 1829). In 1829, Hooker described *A. brevistyla* as a separate taxon. When the flowers and fruit are missing, the taxon has been mistaken for *A. saximontana* (Rydberg 1896). It is not clear when *A. brevistyla* was first collected in Wyoming or South Dakota. Britton (1901) reported that *A. brevistyla* occurred from western Canada to South Dakota. The earliest South Dakota herbarium specimen located for this report (SD 26 in **Table 3**) was collected in 1897, near Rochford in the Black Hills.

Non-technical description

The following description is derived from Payson (1918), Munz (1946), Scoggan (1957), Hultén (1968), Whittemore (1997), and the Montana Natural Heritage Program (2004). *Aquilegia brevistyla* is an herbaceous perennial with a stout rootstock (taproot) and slender woody rhizomes. It has few, sparingly branched, slender stems that are up to 80 cm tall. The stems are lightly covered with soft hairs (pubescent) toward the base. The upper parts of the stem are slightly glandular. The plant has basal leaves and a few leaves on the stem. The basal leaves have long petioles (stalks) and blades that are lobed and wavy-margined. The leaves on the stems are very short-petioled and less-lobed, and the uppermost leaves may be simple and without obvious lobes (entire). In comparison to other *Aquilegia* species, the flowers of *A. brevistyla* are small. The blue to lavender, reflexed sepals are 15 to 25 mm long, and the bluish nectar spurs are stout, hooked, and 6 to 8 mm long. The petals are a yellowish-white (**Figure 1**). The stamens (7 to 11 mm long) and styles (less than 7 mm long and typically less than 5 mm long) barely protrude beyond the petals. The fruit is an aggregate of five follicles that split open when dry. The fruits are approximately 1.5 to 2.5 cm long and are tipped by beaks (styles) that are 2 to 5 mm long. The fruits may be hairless to softly hairy. The seeds are black, obovoid, smooth, and approximately 1.5 mm long. **Figure 2** is a line drawing of the plant.

Rydberg (1896) noted that many early records of *Aquilegia brevistyla* were actually specimens of *A. saximontana*. This has likely led to inconsistencies in some early descriptions of the former. *Aquilegia brevistyla* may also be mistaken for *A. flavescens* (Roe 1992) or *A. canadensis*, particularly when in vegetative condition. *Aquilegia flavescens* flowers have yellow spurs, white or cream-colored blades, and yellow, sometimes pink-tinged, sepals (Nold 2003). Flowers of *A. canadensis* have red spurs, yellow to yellow-green blades, and red, sometimes green-tipped, sepals. An example of a documented case of mistaken identity with the latter is that the name *A. canadensis* var. *hybrida* Hooker was misapplied to *A. canadensis* and the type specimen actually belongs to *A. brevistyla* (Boivin 1953, Whittemore 1997). When plants are vegetative, *Thalictrum* species have also been mistaken for *A. brevistyla*.

References to technical descriptions, photographs, line drawings, and herbarium specimens

Detailed technical descriptions and line drawings of *Aquilegia brevistyla* can be found in Munz (1946), Hultén (1968), Porsild and Cody (1980), and Whittemore (1997). Descriptions of *A. brevistyla* appear in many other publications including Hooker (1829), Britton (1901), Payson (1918), Clements and Clements (1928), Rydberg (1932), Fernald (1950), Rydberg (1954), Scoggan (1957), Van Bruggen (1976), Dorn (1977), Moss and Packer (1983), Dorn (1984), Van Bruggen (1985), Douglas et al. (1991), Dorn (2001), and Hichcock and Cronquist (2001). Descriptions and colored photographs are in Larsen and Johnson (1999) and Nold (2003). *Aquilegia brevistyla* is also very briefly described in Great Plains Flora Association (1986).

Distribution and abundance

The terms "population" and "occurrence" are often used in describing the distribution of a plant taxon. These terms need to be defined in the context of this assessment. A population can be defined as "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). Distinguishing between genetically distinct populations of a certain taxon may be important for conservation planning purposes. Within the known range of a taxon, there may be several genetically distinct populations, each of which is composed of several subpopulations. Alternatively, all the plants within each of its discrete geographic locales might belong to a single extensive metapopulation. That is, apparently discrete populations might be linked by migration and extinctions of intervening populations. This may be particularly true of patches of plants that

Table 3. Information on *Aquilegia brevistyla* occurrences in Wyoming and South Dakota (USDA Forest Service Region 2), including location, land management/ownership, date of observation, abundance and phenology, habitat description, and other comments. Occurrences with the same letter in square brackets [] are near each other but did not fit the criteria that would have made them sub-occurrences within a larger occurrence (see text for details). The botanical or common names of associated plant species are as described by the field observer (see **Table 6** for explanations of botanical abbreviations). The measurement units documented here were those reported by the original surveyor.

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
WY 1	Absaroka Range, Lodgepole Creek/ Crandall Creek area, Park County.	Shoshone National Forest	21 Jul 1924	In flower.	Moist loam.	No information.	*D. Pearson #122* RM, Wyoming Natural Diversity Database (2004)
WY 2	Black Hills: Stockade Beaver Creek east of Mallo Camp; approximately 4 miles east of Four Corners, Weston County.	Black Hills National Forest, Bureau of Land Management (BLM) Newcastle Field Office	19 Jul 1982	In flower and fruit.	Streambank in spruce forest. Streamside thicket (*Symphoricarpos* spp.) (Marriott 1989).	No information.	*H.J. Marriott #1593 with D. Horning*. RM. Wyoming Natural Diversity Database (2004)
WY 3	Drainage into Parmlee Canyon (see SD occurrences 7, 9 and 20), Weston County.	Black Hills National Forest, BLM Newcastle Field Office (may extend onto private land)	29 Jul 2004	Two individual plants in 1 m^2. one vegetative, one immature fruit.	In partial shade in PIPO/ PIGL/BEPA community. Mesic soils.	Base of slope shaded by *Picea glauca*. Past grazing but not currently grazed.	Hells Canyon Ranger District, Black Hills National Forest survey form
WY 4	Black Hills, Bear lodge Mountains, Crook County. Ogden Creek drainage and Tent Canyon drainage. August 7 2002: Ogden Creek area. Approximately 0.6 miles down drain from point of entry. The first rock face encountered going down drain. 9 Aug 2002: Tent Canyon area. Plants were found on a limestone boulder and along base of limestone face approximately half way down drainage - exact location not known.	Black Hills National Forest	7 Aug 2002, 9 Aug 2002	Aug. 7: Eight individuals (five in leaf [vegetative], three mature fruit) observed in a 1 to 5 m^2 area. Aug. 9: one to ten individuals, vegetative and seed dispersing. Observed in a 5 to 10 m^2 area.	August 7: In moist and dry-mesic soil in open area on a north facing vertical rock face on the lower slope., on north facing.August 9: In partial shade at bottom of slope in a limestone/COCO6 (beaked hazelnut) community in dry-mesic soil population on a partially lit, dry mesic bottom slope in a beaked hazelnut community on limestone.	Both dates: On small ledge and crevices on rock face. Plant: one basal leaf, long petioled, glabrous biternately compound, each leaflet three lobed each lobe with three lobes.	Wyoming Natural Diversity Database (2004), Black Hills National Forest survey form 02U290B - Burner Project August 7 2002. Black Hills National Forest survey form 02U320A - Burner Project. August 9 2002

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
WY 5	1997: Black Hills, Surprise Gulch drainage and the lower end of Williams Gulch drainage. 2002: Surprise Gulch: On FS 803 southeast 0.65 miles to first draw on east side of the road. Draw extends for about 3/4 mile. Williams Gulch: Site is on the western side of Williams Surprise Divide and 0.7 miles east of Grand Canyon Creek. Crook County. 2004: Surprise Gulch. In drainage southeast to where the draw parallels Surprise Gulch Road.	Black Hills National Forest	23 Jun 1997, 9 Aug 2002, 2004	23 July 2004	1997: Ponderosa pine/paper birch/beaked hazelnut community in a moist draw bottom. No information on occurrence in 1997, save that plants were observed in a draw from Surprise Gulch. 2004: survey explained a discrepancy in the initial location description. In partial shade in mossy north-northwest facing draw with a birch and hazelnut community with thick shrub and forb layer. No running water but mesic soils. Plants occur along drainage bottom.	2002: Questionable ID, observed by S. Corey and K. Zacharkevics 2004: Only approximately 0.3 miles surveyed; whole drainage needs to be surveyd. Many stems had more than four and up to seven fruits per head. Plants may be mistaken for *Aquilegia canadensis* when not in flower. No spruce or exposed limestone. *Botrychium virginianum* also found in bottom. *Cynoglossum officinale* occurs along old roadbed above the site.	Wyoming Natural Diversity Database (2004), Black Hills National Forest survey form 02U290B - Burner Project August 7 2002. Black Hills National Forest survey form 02U320A - Burner Project. August 9 2002
SD 1	Jewel Cave 18 miles west of Custer.	National Park Service or Forest Service	9 Jul 1927	No information.	2004: survey explained a discrepancy in the initial location description. In partial shade in mossy north-northwest facing draw with a birch and hazelnut community with thick shrub and forb layer. No running water but mesic soils. Plants occur along drainage bottom.	No information.	*H.E. Hayward #2104* 1927 RM
SD 2	Box Canon, Lawrence County.	Black Hills National Forest	30 Jun 1928	No information.	No information.	No information.	*W.H. Owen (maybe mis-spelt) #17584* 1928 RM
SD 3	Boulder Canyon, Bear Butte Creek.	Black Hills National Forest	17 Jun 1927	No information.	Mesophytic canyon with oak, willow and *Populus* sp.	No information.	*H.E. Hayward # 1073* 1927 RM

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 4	a) Drainage near Bald Hills. b) Drainage west of Bald Hills. c) *Aquilegia brevistyla* population at confluence of Bear Run Creek and a west running draw.	Black Hills National Forest	30 Jul 2004	a) 51 to 100 individual plants (20 percent vegetative, 80 percent immature fruit) in 50 to 100 m^2. b) 101 to 500 individual plants. 50 percent vegetative, 50 percent immature fruit. c) 11 to 51 individual plants in 2 acres. 100 percent immature fruit.	a) On lowerslope in shade with PIGL. Mesic soils. b) At bottom of slope in shade of PIGL/POTR5. Mesic soils. c) On lowerslope in shade with PIGL. Mesic soils.	a) Base of slope in shade of *Picea glauca* along Bear Run. b) Along *P. glauca* shaded bottom and base of slope and on limestone faces along north facing portion of Bear Run. Cattle grazing. c) Mossy steep slope shaded by *Picea glauca*.	a, b & c) Hells Canyon Ranger District, Black Hills National Forest survey forms
SD 5	*Aquilegia brevistyla* population where drainage from north meets Little Bear Run.	Black Hills National Forest	31 Apr 2004	One individual plant in 1 m^2.	On lower slope in shade in PIPO/PIGL/BEPA community. Dry-mesic soils.	Botton of drainage shaded by *Picea glauca*.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 6	1984: West of FR 109 and east of Beaver Creek Campground. 2004: a) Hillside immediately west of Beaver Creek campground. b) Beaver Creek approximately 0.2 miles up trail from Beaver Creek Campground, population starts at the base of a northwest facing slope. c) Approximately 0.2 miles up trail from Beaver Creek Campground, population starts at the base of a northwest facing slope. d) For approximately 0.4 miles along draw (Beaver Creek Ski Trail) from Beaver Creek Campground. e) Along Beaver Creek, east of Beaver Creek Campground.	Black Hills National Forest	July 1984, a) 2 Jul 2004, b) 14 Jun 2004, c and d) 25 Jul 2004, e) 26 Jul 2004	2004: a) One individual in flower in 1 m^2. b) Four individuals in less than 5 m^2. 50 percent vegetative, 50 percent flowering. c) 51 to 100 individual plants. 20 percent vegetative, 2 percent flower, 78 percent immature fruit. d) 11 to 51 individual plants in 2 acres. 20 percent vegetative, 2 percent flower, 78 percent immature fruit. e) 101 to 500 iindividual plants in 2 acres. 10 percent vegetative, 90 percent immature fruit.	a) On lowerslope in shade with PIGL. Mesic soils. b) At bottom of slope in an area with heavy violet cover and partial shade from spruce overstory. Dry mesic soils. 0 to 10 percent slope. *Picea glauca*, *Sambucus racemosa*, *Juniperus communis*, *Viola* spp., *Geranium richardsonii*, *Taraxacum* spp., *Maianthemum stellatum*, *Spireaea* spp., and *Poa* spp. c) On lowerslope in partial shade with PIGL. Mesic soils. d) On lowerslope in partial shade with PIGL/PIPO/ POTR5/BEPAMesic soils. e) On lowerslope in shade with PIGL/POTR5. Mesic soils.	a) Plant at base of *Picea glauca*. Occurrence within sight of campground. b) Receation. c) Along base of toe slope and in bottom. Cattle grazing. d) Recent logging at base of slope involved cutting of PIGL. Logging (past) and cattle grazing. e) Shaded north-facong toe slope, shaded slopes below limestone outcrops 0 to 40 feet from base, in PIGL and PIGL/POTR. Cattle grazing.	*P.L. Hansen #1218* 1984 SDU. 2004: a) Hells Canyon Ranger District, Black Hills National Forest survey form. b) Black Hills National Forest survey form # 04AB01A. c, d & e) Hells Canyon Ranger District, Black Hills National Forest survey forms

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 7	a) South of Beaver Creek campground in Dry Parmlee Canyon. *Aquilegia brevistyla* is along the toe slope. b, c & d) South east of Beaver Creek Campground. *Aquilegia brevistyla* is along toe slope southwest of the road.	Black Hills National Forest	23 Jul 2004	a) 101 to 500 individual plants in 2 acres. 10 percent vegetative, 90 percent flower. b) 11 to 51 individual plants in 2 acres. 100 percent mature fruit. c) Six individual plants in 5 to 10 m^2. Two immature fruit. d) 51 to 100 individual plants in 2 acres. 100 percent immature fruit.	a) At bottom of slope in shade of PIGL. Mesic soils. b) On lowerslope in shade with PIGL. Mesic soils. c) On lowerslope in shade with PIGL. Mesic soils. d) On lowerslope with PIGL. Mesic soils.	a) Base of toe slope on north facing hillside, toe slope is usually steep and AQBR occurs near where it becomes the flattened bottom and bases of vertical limestone outcrops. Active cattle grazing. b) Steep northeast facing toe slope, shaded by PIGL about 50 feet up from grassy valley bottom; plants are healthy some have been grazed by cattle. Active cattle grazing. c) Steep northeast facing toe slope, shaded by PIGL about 40' from grassy valley bottom; plants are healthy some have been grazed by cattle. Active cattle grazing. d) Lower slope under spruce, 5 to 15 feet above base of slope. Individuals are scattered. Currently active cattle grazing.	a,b,c, & d) Hells Canyon Ranger District, Black Hills National Forest survey forms

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 8 [A]	Hike down a few hundred feet above Wet Parmlee Canyon.	Black Hills National Forest	24 Jul 2004	a) Six individual plants in 1 m^2; five vegetative, one mature fruit. b) 51 to 100 individual plants in 2 acres; 25 percent vegetative, 75 percent immature fruit. c) 51 to 100 individual plants 20 percent vegetative, 80 percent immature fruit in 2 acres.	a) Midlope in shade of PIGL/ BEPA. Mesic soils. b) Bottom of slope in PIGL community. Mesic soils. c) On lowerslope in shade with PIGL. Mesic soils.	a) *Aquilegia brevistyla* growing in thick moss in steep drainage. Shaded by *Picea glauca*. Plants are small with some leaves missing. b) Base of toe slope and into shaded drainage bottom, sporadic occurrence from flag near east end of polygon to west end in canyon. Cattle grazing. c) On upper toe slope and at base of slope along canyon bottom. Cattle grazing.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 9 [A]	a) Bear Canyon; population is in Canyon. b) Populations along drainage and Bear Canyon. c) Populations along drainage and Bear Canyon. d) Bear Canyon Drainage Population lies along north end of drainage.	Black Hills National Forest	27 Jul 2004	a) 11 to 51 individual plants (100 percent flowering) in 2 acres. b) 11 to 51 individual plants (100 percent immature fruit) in 2 acres. c) 11 to 51individual plants in 2 acres. d) 51 to 100 individual plants (100 percent immature fruit) in 50 to 100m^2.	a) On lowerslope in partial shade of PIGL/BEPA community. Dry-mesic soils. b) At bottom of slope in shade of PIGL/BEPA. Mesic soils. c) At bottom of slope in shade of PIGL. Mesic soils. d) In shade of PIGL. Mesic soils.	a) On vertical north facing limestone outcrop about 15' above drainage bottom. b) *Aquilegia brevistyla* in bottom and along toe slope, usually shaded by *Picea glauca*. c) On toe slope and at bottom beneath *Picea glauca* and on north and east facing slopes. d) On lowerslope and bottom shaded by *P. glauca*. Cattle grazing.	Hells Canyon Ranger District, Black Hills National Forest survey form

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 10	Approximately 1/8 miles east of draw where FSR 129 crosses draw, approximately 1.2 miles from FSR 129 and Flag Mountain Road Junction.	Black Hills National Forest	2004	35 dividuals in 50 to 100 m^2. 15 (47 percent) vegetative, 10 (27 percent) with fruit and 10 (27 percent) individuals in flower.	*Aquilegia brevistyla* occurs in partial shade in mesic soils on the southern lower slope of an open west-facing draw. The slope faces north. The slope has thick spruce cover with dead downed timebr. The plants grow near the downed spruce.	AQBR-43 (first found in 2003). Open to logging and grazing. Some of the spruce near the *Aquilegia* were marked with blue paint [suggesting the area will/has been logged or scheduled for forest thinning]. The draw below the slope is partially open and grassy. There were cattle there the day of the survey.	Black Hills National Forest survey form # 04AB09A
SD 11	North up Coulsen Hughes Draw (FDR 591). At base of slope near a downed spruce tree.	Black Hills National Forest	8 Jul 2003	101 to 500 in 50 to 100 m^2.	In PIGL/LOBO3 community on toe of slope under 70 percent canopy cover.	Grazing and recreation.	Black Hills National Forest survey form 03C05A - Coulsen Project
SD 12	Drainage of Stots Canyon.	Black Hills National Forest	25 Jul 2004	13 individual plants in 1 to 5 m^2.	At bottom of slope in shade in PIGL community. Mesic soils.	In steep drainage bottom about 15' wide. Most AQBR are growing in moss. Appear to be in good health. AQBR occur along the lower end of the tributary to Stots Canyon.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 13	a & b) Along Thompson Canyon road; suboccurrences are approximately 0.25 mile apart.	Black Hills National Forest	22 Jul 2004	a) Five individual plants in 1 m^2 one vegetative, four immature fruit. b) 11 individual plants in 5 to 10 m^2. 11 immature fruit.	a & b) On lowerslope in shade in BEPA/ACNE2 community. Mesic soils.	a) Steep toe slope near base, often found where ACNE2 found. Active cattle grazing. b) Scattered from base of limestone outcrop halfway to dry creek bed. Active cattle grazing.	a & b) Hells Canyon Ranger District, Black Hills National Forest survey forms

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 14	Along South Fork Castle Creek Drainage.	Black Hills National Forest	2004	No information.	Plants in partial shade at bottom and on lower and mid position on *Picea glauca* dominated northerly facing slopes and creek bottom. Northerly facing slopes are mossy and often dominated by *Linnea borealis*. Rock substrate changes from sandstone to limestone as you progress down the drainage. More plants are found directly growing on the rock in limestone area. Mesic soils. Slopes up to >51 percent.	Grazing.	Black Hills National Forest survey form # 04AB03A, *Mayer #294* FS
SD 15	On Road 612 approximately 0.3 miles east of junction with Ditch Creek Road (FSR 291).	Black Hills National Forest	6 Jul 2004	55 individuals occupying 50 to 100 m^2, 43 vegetative, 30 in flower, and 27 percent with matutre fruit.	On the bottom of a mossy shaded drainage in moist soils. The drainage bottom is flat for about 10 feet across and then abruptly begins to slope on both the northern and southern sides. Spruce is the dominant overstory in the area with a few scattered pines here and there.	No information.	Black Hills National Forest survey form # 04AB07A
SD 16	Ditch Creek.	Black Hills National Forest	14 Jun 1956, 28 Jun 1984	1956: Uncommon.	1956: At 6,400 feet on slope (2 percent north). Silty clay soil, park vegetation type. *Calamagrostis canadensis*, *Carex* spp., and *Smilacina stellata*. Wet meadows, open timber. 1984: No information.	No information.	*C.P. Pase #553* 1956 RM, *P.L. Hansen #1225* 1984 SDU

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 17	Ridge running northwest from Forest Road 189 just west of Crook Tower; limestone cliff band just below crest on northeast side. Site revisited in 2002 (02X02).	Black Hills National Forest	27 Aug 2001	100 to 300 individuals along 0.6 miles.	In partial shade to shade conditions on upper slope on vertical face of limestone outcrop.	Dry microsite but shaded northerly aspect; occurs on small moss ledges on limestone cliffs, around cliff bases and rocky gullies. Grazing and logging but cliff band not affected.	Black Hills National Forest survey form 01X020A - Power Timber Sale Project. *Marriott #12344* FS
SD 18	South of FDR 267.	Black Hills National Forest	23 Jul 2003	101 to 500 indivuals in 2 acres.	In mesic soils in *Picea glauca* community.	Grazing and recreation.	Black Hills National Forest survey form 03N04A - North Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 19 [B]	a & b) Forest road 109.3A (Parmlee Canyon). c) Small drainage a few hundred feet south of a livestock tank. Approximately 1 to 1.5 miles north of Beaver Creek Campground. d) North of Beaver Creek Campground. e) Near part of the Beaver Creek Ski Trail system. f) North facing slope covered with PIGL on the south side of 109.3 E.	Black Hills National Forest	a & b) 22 Jul 2003, c) 20 Jul 2004, d & e) 28 Jun 2004, f) 27 Jun 2003	a) 51 to 100 (only with leaves) in 50 to 100 m^2. b) 51 to 100 in 50 to 100 m^2, 90 percent only with leaves, 10 percent have mature fruit. c) One individual plant (one flower) in <1 m^2. d) 100 to 500 individuals occupying approximately 0.5 acres in an area of 2 acres of potential habitat surveyed. e) 101 to 500 individuals in approximately 0.5 acre; three areas of potential habitat surveyed. f) 51 to 100 over 0.01 miles. 60 percent leaf, 20 percent bud and 20 percent flower.	a) In PIGL community on 31 to 40 percent slope in mesic soil. b) In PIGL community in mesic soil on lower slope. c) At bottom of slope in partial shade of PIGL/PIPO/POTR5 community. Dry-mesic soils. d) In partial shade on a northwest to north-facing slope dominated by *Picea glauca* with scattered chunks of limestone and considerable moss and lichen cover. Mesic soils. Limestone soils. e) Plants in partial shade on mossy rich north facing spruce slope with small areas of broken limestone cliff band going along midslope. Soil is soft and loose with lots of decomposed organics and litter. Plants are scattered on lower slope, on flat areas near the base of the slope and occasionally on limestone rocks higher up. Mesic soil. f) In PIGL community.	a) Grazing and recreation. b) Grazing and recreation. c) Plant is healthy, 1ft. tall, at break in slope from very steep lower backslope to gently sloping valley. AQBR is partially under and shaded by *Picea glauca*. Active cattle grazing. d) AQBR-U.Active cattle grazing. Many plants occur beside old road that is now part of the Beaver Creek ski/hiking trail and are scattered consistently on the lower slope above the road. Moss and lichen abundant on slope. Some plants found growing on limestone. e) AQBR-V. *Cynoglossum* scattered. Site is adjacent to hiking/ ski trail. Livestock graze in the bottom and lower slope. Cattle trails go through bottom with a few trails going up the slope into the site area. This is an area with lots of moss and loose soil and is easily damaged by over trampling. f) Grazing and recreation.	a) Black Hills National Forest survey form 03N02A - North Project b) Black Hills National Forest survey form 03N03A - North Project c) Hells Canyon Ranger District, Black Hills National Forest survey form d) Black Hills National Forest survey form #04AB05A, *Mayer #320* June 28 2004 FS e) Black Hills National Forest survey form #04AB05A, *Mayer #319* June 28 2004 FS f) Black Hills National Forest survey form 03N01A - North Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 20 [B]	Across a meadow south of Sanders Corral (may be associated with SD occurrence 20).	Black Hills National Forest	21 Jul 2004	Five individual plants in 1 to 5 m^2.	On lowerslope in shade with PIGL/PIPO. Mesic soils.	Very steep northfacing lower backslope. PIGL overstory. Site is rocky (limestone) that is heavily covered with moss. AQBR are growing in thick moss. Plants appear healthy, only one has fruit. Active cattle grazing.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 21	Southeast of Crooks Tower, in vicinity of FSR 631.	Black Hills National Forest	15 Aug 2003	No information.	No information.	No information.	Black Hills National Forest survey form 03N05 - North [timber sale] Project
SD 22	1973: Black Fox Canyon, Pennington County. 2002: Black Fox Bog.	Black Hills National Forest	2 Jul 1973 23 Jun 2002	No information.	1973: Rich woods and boggy creek. 2002: Bog dominated by *Betula papyrifera*, *B. glandulosa*, *Salix* spp. and *Sphagnum* spp.	No information.	*T. van Bruggen #6400* 1973 SDU, *A. Gabel #sn* 2002 BHSC
SD 23	Near Black Fox Campground.	Black Hills National Forest	13 Jun 1970	No information.	No information.	No information.	*D. Rogers #s.n.* AUG
SD 24	a) Along road 184 that goes down Bloody Gulch just west of drainage. b) Lower north-facing slope above Bloody Gulch.	Black Hills National Forest	a) 30 Aug 2001, b) 23 Jun 2004	a) Several dozen in seed. b) Approximately 125 individuals in 0.5 acres; occupying approximately 10 percent of potential habitat surveyed.	a) In moist soil in partial shade, north aspect on lower slope. b) In partial shade on lower to mid position on north-facing slope. Community dominated by *Populus tremuloides* and scattered *Picea glauca*. Fairly thick and diverse forb layer. Mesic soils.	ID not sure in field; took seed pod and in December determined to be *Aquilegia brevistyla*.	a) Black Hills National Forest survey form 01R150A - Rochford Timber Project. b) Black Hills National Forest survey form #04AB02A; *Mayer #313* FS
SD 25	Ward Draw.	Black Hills National Forest	11 Jun 1985	No information.	Several plants on lower, shaded northwest-facing slope in *Picea glauca* forest. 5,800 ft.	No information.	*R. Tatina #2042* DWU

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 26	15 Jun 1897: Near Rochford, northern Black Hills. July 9 2004: On a slope above the Mickelson Trail and south to where FS Road 231 curves to the left.	Black Hills National Forest	15 Jun 1897, 9 Jul 2004	July 9 2004: 50 to 100 individuals in 50 to 100 m. 75 percent vegetative, a few in flower; 25 percent with fruit. Approximately 7 acres of potential habitat were surveyed.	15 Jun 1897: meadow at 5300'. July 9 2004: In partial shade on mossy north-facing spruce dominated slope. On mesic and dry-mesic soils. The largest patch of *Aquilegia brevistyla* in the area where slope curves to northwest-facing (300 deg) and it gets drier with more Ponderosa pine present. More plants on lower slopes; some individuals were found higher up the slope in very mossy lush area. Those plants occurring next to trail in a very open, rocky condition without moss.	July 9 2004: AQBR-T. Could be confused with *Aquilegia canadensis* when not in flower.	*A. Travers #sn* 15 Jun 1897 BHSC Black Hills National Forest survey form #04AB08A, *Mayer #341* July 9 2004 FS
SD 27	On west side of Gimlet Creek.	Black Hills National Forest	23 Jun 2004	Approximately 100 indivdiuals occupying 1 acre - areas of potential habitat surveyed = approximately 5 acres; occupying approximately 10 percent of potential habitat surveyed.	Plants in partial shade on mossy benches and on lower north facing slope dominated by *Picea glauca. Picea glauca* extends into the botton in some areas. Ponderosa pine dominates upper slope. Bottom, open with *Symphoricarpos occidentalis* and small patches of *Salix*. *Aquilegia* also occurs on very steep (100 percent) slope) moss covered slate talus. Mesic soils.	Grazing.	Black Hills National Forest survey form #04AB04A
SD 28	South side of Jim Creek approximentaly 1.1 miles from junction between US 385 and FSR 208.1.	Black Hills National Forest	18 Sep 2003	One to 10 in 50 to 100 m^2.	Under shade of pine/spruce community in moist soils on the lower slope.	No reproductive material; identification also based upon habitat. No [defined] uses, but the site occurs along a stream between 2 parcels of private land.	Black Hills National Forest survey form 03BM80B

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 29	Southeast side of FS 376 (Redbird Canyon Road) west of Compton Spring.	Black Hills National Forest	28 May 2004	11 to 50 in 10 to 50 m^2.	At bottom and on lower slope in partial shade in a PIPO/ PRVI community. Mesic soils.	Limestone outcropping is shaded in afternoon. Some individuals right on road. Cattle grazing.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 30	Along limestone outcropping approximately 0.6 miles south of Bear Mountain lookout tower.	Black Hills National Forest	16 Nov 2004	Four in 1 to 5 m^2.	At bottom of slope in partial shade in PIGL/PIPO/POTR5 community. Mesic soils.	Area needs to be resurveyed during season, adjacent *Pinus ponderosa* has recently been harvested. Logging and grazing allotment.	Hells Canyon Ranger District, Black Hills National Forest survey form
SD 31	Oreville, Black Hills.	Unknown	1924 to 1931	Locally common.	On rocky shaded slopes.	No information.	McIntosh (1931)
SD 32	30 May 1966: Spring Creek in Black Hills. 24 Sept 2004: On the south side of Spring Creek, approximately 1.5 miles west of Highway 16 [Within 2 miles southwest of Oreville].	Black Hills National Forest	30 May 1966, 24 Sep 2004	24 Sept 2004: 11 to 50 individuals occupying approximately 1 acre in the 3 acres of potential habiat surveyed.	30 May 1966: Shady, rich north slope. 24 Sept 2004: In partial shade and mesic soils on a mossy north northeast facing spruce dominated slope with occasional scattered pine and birch, pine becomes more common higher up the slope. *Aquilegia brevistyla* is more common on the lower slope. There is a trench (old flume?) above the creek in some areas and *A. brevistyla* is found on a vertical schist cliffband above the trench.	30 May 1966: Garden grown at Smithwick, SD from this (Spring Creek) locality. 24 Sept 2004: *Cirsium arvense* is scattered sparsely in the same *A. brevistyla* habitat at the site. Plants may be mistaken for *A. canadensis* but a fruit was found that could be used for positive identification. A lot of downed spruce is on the slope. Slope is quite mossy with *Peltigera* lichen abundant in areas. Area exposed to grazing but no cattle traffic evident on slope.	*C.L. Barr #962* May 30 1966 RM. Black Hills National Forest survey form #04AB10A Sept 24 2004

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 33	Approximately 700 m south from lost Cabin Trail along Nelson Creek.	Black Hills National Forest	23 Sep 2003	Four flowering stems; 100 percent dormant. In <1 m.	Near Creek channel. In partial shade in mesic soil in PIPO/ PIGL/BEPA community.	Ground water cover wood 2 percent, water 10 percent. *Aquilegia brevistyla* found on mossy granite rock on bank of Nelson Creek northwest facing aspect. Use of site as drainage.	Black Hills National Forest survey form 03I450K – Iron Mountain Project
SD 34	Approximately 0.9 miles north of Remington Camp along FSR 345 and about 0.5 miles past FSR 348.	Black Hills National Forest	7 Oct 2003	>35 individuals with leaves.	In moist soil in partial shade on lower slope in spruce birch community.	Recreation appears to be only current use of site - there are no factors that would draw individulas to the slope where *Aquilegia brevistyla* occurs.	Black Hills National Forest survey form 03BM70A
SD 35	East of Hardy (Crooks Tower quad).	Black Hills National Forest	28 Jul 2002	500 to 1,000 fruiting stems.	In shade to partial shade in dry-mesic soil in PIGL/LIBO3 and PIGL/VASC.	The columbine was found in much of the survey area except in more open stands of PIPO/JUCO6 on mid-upper slopes. It seems to be somewhat more common near limestone outcrop.	Black Hills National Forest survey form 02X200A - Power Timber Sale Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 36	a, b, and c) East of Potato Spring north and south of Spearfish Creek.a) First plants are near limestone face when slope begins to curve into north-south drainage. Remaining population is across drainage and scattered throughout slope. b and) Intermittant throughout survey site except on lowermost slopes.	Black Hills National Forest	a) 17 Jun 2002, b) 14 Jul 2002, c) 15 Jul 2002	a) 50 to 100; 50 percent in bud and 50 percent leaf. b) 51 to 100 flowering stems. Fruit. c) Approximately 30 flowering stems seen. In fruit.	a) In moist soil in partial shade on upperslope. b) In dry-mesic soils in partial shade with PIGL/VASC, PIGL/LIBO3. c) In dry-mesic soil in PIGL/VASC and PIGL/LIBO3 communties.	a) Site is very dry for this time of year; the ground should be very moist and mossy but mineral soil is bone-dry at least 2 to 3 inches below surface and moss turning brown. b) Bare ground cover includes litter and downed wood. Throughout area, more common at base of limestone outcrops and on slopes immediately below. These slopes are very difficult to survey due to steepness and downfall. c) Columbine is intermittant throughout survey site, population surely larger; area is very difficult to survey.	a) Black Hills National Forest survey form 02X990B - Power Project b) Black Hills National Forest survey form 02X080B - Power Timber Sale Project c) Black Hills National Forest survey form 02X120A- Power Timber Sale Project
SD 37	East southeast of O'Neil Pass, US hghway 85 and just west of Crooks Tower on northwest trending ridge approximately 15.7 miles southsouthwest of Lead.	Unknown	28 Aug 2001	No information.	At base of north facing limestone outcrop near ridge crest under *Picea glauca* at 7,000 ft.	No information.	*Marriott, H. J. #12344 with C. Mayer* RM

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 38	a, and b) North, northwest and west of Clayton II Quarry. Crooks Tower quad. c) Plants were found downstream on lowermost steep slopes and occasionally on mid-slope with sufficient tree cover (shade).	Black Hills National Forest	a and b) 28 Jul 2002 c) 30 Jul 2002	a) 100 to 300 fruiting stems. b) 101 to 500 flowering stems. Late flower and fruit. c) 30 to 50 fruiting stems. In fruit.	a) In partial shade to shady areas on the bottom and mid-slope under PIGL/LIBO3. b) In dry mesic soils in shade in PIGL/LIBO3, PIGL/VASC on bottom to mid slope. c) In dry-mesic in partial shade on lower to mid slope under PIGL.	a) Plant occurs throughout the survey site on lower to mid slope and in the small drainage bottom. Plant seems somewhat more common around small limestone outcrops. Bottom is grazed. b) *Aquilegia brevistyla* is intermittant across survey site, but is somewhat more abundant at base of limestone outcrops and on slope immediately below. It is present but uncommon in areas of heavy forb cover at base of slope. c) *A. brevistyla* appears to be more common near limestone outcrops.	a) Black Hills National Forest survey form 02X190A - Power Timber Sale Project b) Black Hills National Forest survey form 02X070A - Power Timber Sale Project. Marriott #12373 c) Black Hills National Forest survey form 02X230B - Power Timber Sale Project
SD 39[C]	Near Spearfish, Northern Black Hills.	Black Hills National Forest	22 May 1902	No information.	Rich, moist shady places.	No information.	*A. Uhlig #s.n.* BHSC

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 40 [C]	a) In draw of Little Spearfish Creek approximately 0.6 to 0.8 miles from the Rod and Gun campground. b) In draw of Little Spearfish Creek approximately 0.6 to 0.8 miles from the Rod and Gun campground. c) From rim rock trailhead at Rod and Gun campgrouund follow trail west to gate. d) Along northeast facing slope along USFS road 223, at approximately the region where the road turns sharply south (from its east direction). e) Approximately 0.6 miles northeast of Rod and Gun campground along FS 222.1, south and southwest of Rim Rock Trail. f) Population is located south of Rimrock trail at base of limestone outcrop. g) Population is 0.1 miles west of Rim Rock trail in floodplain of little Spearfish Creek in a southeast-facing draw. h) Slope at point where a culvert runs under FR 222.1 road and Spearfish Creek switches to the south side of the road. i) Slope at point where a culvert runs under FR 222.1 road and Spearfish Creek switches to the south side of the road. j) East from the Rod and Gun campground to large draw.	Black Hills National Forest	a, b & g) 26 Jul 2002 c) 27 Jul 2002, 26 Jul 2002 d) 24 Jul 2002 e, f & j) 25 Jul 2002 h & i) 22 Jul 2002	a) One individual occupying approximately 0.5 m^2, vegetative. b) One individual occupying approximately 1 m^2, vegetative. c) Ten plants in 20 m^2; 50 percent fruit, 50 percent vegetative. d) Twelve vegetative or past fruiting individuals in 300 m^2. e) Twelve vegetative individuals in 10 m^2. f) One fruiting individual in 1 m^2. g) Two individuals in 0.5 m^2, vegetative. h) Four, vegetative but one dried flowering stalk. i) One individual; 100 percent vegetative. j) Five individuals in 25 m^2. Vegetative.	a) In partial shade on lower slope in dry mesic soil in PIGLD-PIPO-BEPA. b) Open exposure in dry mesic soil on mid-slope with a 50 percent incline in BEPA/ PIGL/PIPO. North aspect. c) On 54 percent incline on lower slope in moist soil under partial shade in PIGL, BEPA, PIPO community. d) In partial shade on lower slope in dry mesic soil in PIPO/BEPA/COCO6/ARNU2. e) In dry-mesic soils under shade on lower slope at a 57 percent incline. f) In dry-mesic soils in open site on flat area mid-lower slope at a 70 percent incline in PIPO/PIGLD/COCO6/ ORAS. g) In dry mesic soil in shade on lower slope with PIGLD/ PIPO/BEPA community. h) On upper slope in moist soil under partial shade in PIPO/BEPA/ PIGLD/POTR5. i) Populations located along steep north-facing limestone cliffs. In partial shade on upper slope in moist soil in PIPO, BEPA, PIGLD, POTR5. j) In dry-mesic soils in partial shade with BEPA/COST4/ RUPU/CTFR2.Limestone gully rich in moss, liverworts and CYFR2.	a) *Aquilegia brevistyla* growing at foot of limestone cliff on thin soil with ARLO5. c) *Aquilegia* growing on shelves of limestone cliff. Hiking trail nearby. e) Rimrock hiking trail at base of site. *Aquilegia* on north facing limestone outcrop - occurring sporadically as single individuals - also found in drainages. f) Hiking trail. g) *Aquilegia brevistyla* on shelf of rocky outcrop in drainage. h and i) *Aquilegia brevistyla* growing on mossy limestone j) *Aquilegia brevistyla* growing on rocks on gully bottom, topographically shaded by bedrock gully sides.	a) Black Hills National Forest survey form 02N030 - Geranium Project b) Black Hills National Forest survey form 02N040 - Geranium Project c) Black Hills National Forest survey form 02N040M - Geranium Project d) Black Hills National Forest survey form 02G780D - Geranium Project e) Black Hills National Forest survey form 02N020A - Geranium Project f) Black Hills National Forest survey form 02N020J - Geranium Project g) Black Hills National Forest survey form 02N030D - Geranium Project h) Black Hills National Forest survey form 02G900L - Geranium Project i) Black Hills National Forest survey form 02G900 - Geranium Project j) Black Hills National Forest survey form 02N190H - Geranium Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 41 [C]	Spearfish Canyon, Northern Black Hills.	Black Hills National Forest	23 Jun 1938, 11 Jul 1947	No information.	23 Jun 1938: Shady, rocky talus of spruce at 4500 feet, 11 Jul 1947: Open deciduous woods in entrance to canyon, stony soil at 3,700 ft.	No information.	*F.L. Bennett #s.n.* June 23, 1938 BHSC; *F.L. Bennett #s.n.* July 11, 1947 BHSC
SD 42 [C]	1924: Spearfish Canyon, Savoy, SD at RM; Spearfish Canyon near Savoy, SD at SDU. r) Across from the Rim Rock trail head.	Black Hills National Forest	4 Jul 1924, r) 23 Jul 2002	r) Approximately 45 individuals over approximately 3 acres. 10 percent with seed and 90 percent vegetative.	1924: In shade. r) All *A. brevistyla* located among limestone rocks on mossy north facing slope with PIPO, BEPA, PIGLD, POTR5 in moist-dry soils. Plants in partial shade on lower and mid slope.	No information.	*A.C. McIntosh #s.n.* 1924 RM; *A.C. McIntosh #A21* 1924 SDU r) Black Hills National Forest survey form 02G910 - Geranium Project
SD 43 [C]	Spearfish Canyon, 1.3 miles west of Cheyenne Crossing.	Likely Black Hills National Forest	20 Jun 1998	No information.	Growing in *Picea glauca* habitat, partial sun, cool moist area with species of *Lolium*, *Fragaria*, *Rubus*, *Rosa*, *Prunus virginiana*, and *Actea rubra*.	No information.	*E. Ebbert #82* 1998 BHSC

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 44 [C]	k) Just past Timon campground to beginning of Rim Rock Trail where it crosses the road. Population is along draw bottom on limestone outcrop. l) Population is near the trail head at base of limestone, just past Timon Campground to beginning of Rim Rock Trail. m) South of FSR 222.1 and east of FSR 134.1. n) East of FS road 134.1; 0.33 mile northeast of turnoff to 393. o) Slightly west of of red brick limestone outcrop near start of upper Spearfish Creek hiking trail. p) Hiking trail towards Upper Spearfish Creek trailhead occurrence upslope from trail approximately 1/8 mile south southwest of trailhead/ parking area. q) Northeast of Rod and Gun Campground along FS 222.1 south and southwest of Rim Rock Trail.	Black Hills National Forest	k & l) 26 Jul 2002 n & o) 22 Jul 2002 p & q) 23 Jul 2002	k) 50 individuals in 5 m. l) >25 individulas in 10 m. Vegetative. n) 100 individuals; in fruit (green and dry). o) >200 individuals in one acre. 100 percent fruit. p) Five individuals in 10 sq m. In fruit. q) >20 individuals, fruiting and vegetative, in 25 ft^2.	k) In moist soil in partial shade on bottom-lower slope in PIGLD-BEPA/COCO6-COST4. l) In moist soil on mid slope. m) On upper and lower slopes in dry-dry mesic soils. Total canopy cover 20 to 65 percent,.with PIPO, PIGLD, POTR, BEPA and LIBO3, ARNU2, COST4, SPBE2, ARUV, SHCA. n) In partial shade on lower slope at 65 percent incline in dry mesic soils in PIPO/PIGL/ BEPA/JUCO6 o) In moist soil under partial shade on lower slope with PIGL-PIPO/ JUCO6/ARNU2-C. p) In dry mesic soils in partial shade with in PIPO-PIGL-BEPA/ JUVO6-CO on mid slope. q) In moist soil and shade with north aspect on lower slope in PIPO-BEPA/COVO6-AMAL2.	k) Red squirrel cone leavings at cliff base. l) Trail at end of site - populations found along base of limestone. n) Fairly open portion of lower slope; *Aquilegia brevistyla* identification based on short beaks on follicles (~2mm long). Cattle grazing. o) Past logging. *Aquilegia brevistyla* spread on lower north facing slope near stream. p) Hiking trail at base of slope. Distribution of *A. brevistyla* rather limited. q) Cliffs and heavy tree cover. Adjacent to USFS road 223.	k) Black Hills National Forest survey form 02G980F - Geranium Project l) Black Hills National Forest survey form 02G980A - Geranium Project m) Black Hills National Forest survey form 02N200 - Geranium Project n) Black Hills National Forest survey form 02N100C - Geranium Project o) Black Hills National Forest survey form 02G710B - Geranium Project p) Black Hills National Forest survey form 02G750A - Geranium Project q) Black Hills National Forest survey form 02G770B - Geranium Project
SD 45 [C]	a) East of FS road 222.1 approximately 0.5 miles from junction with US alt 14, revisit of "94T45". b) Located above creek approximately 0.2 miles northeast of Roughlock Falls picnic area, south of FS road 222.1 on west-northeast facing slopes.	Black Hills National Forest	a) 27 Jul 2002 b) 1 Sep 2002	a) Two individuals in 1 m^2. Vegetative. b) 50 (no information status) scattered.	a) In partial shade at bottom of slope in moist soil in BEPA/PIPO. b) In dry dry mesic soil on upper to lower slope.	a) *Aquilegia brevistyla* on limestone outcrops at base of slope. b) One subpopulation with 20 plants occurs at base of cliff; shaded by cliff, but otherwise open, growing on rubbly soil.	a) Black Hills National Forest survey form 02N230H - Geranium Project b) Black Hills National Forest survey form 02N220G - Geranium Project
SD 46 [C]	South of East Spearfish Creek between Hanna campground and Wildcat Gulch. Site where stream crosses the road.	Black Hills National Forest	24 Jul 2003	No information.	No information other than a few individuals of *Moneses uniflora* was also found.	No information.	Black Hills National Forest survey form 030140

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 47 [C]	Botany Bay.	Black Hills National Forest	16 Jun 2001	No information.	Moist limestone canyon, thick, mostly hardwood canopy cover.	No information.	*S. Weins #s.n.* BHSC
SD 48 [C]	a) In Maurice Gulch, approximately 500 feet from the confluence with Spearfish Canyon. b) In drainage approximately 1 mile north of Maurice on Highway 14 (Spearfish Canyon).	Black Hills National Forest	31 Jul 2003	a) One individual occupying approximately 1 m^2, with seed. b) Five individuals in 1 sq m 100 percent vegetative.	a) In partial shade in moist soil on bottom of slope with a 0 to 10 percent incline in BEPA/PIGL/PIPO. b) In moist soil under partial shade at bottom of slope with PIGL/BEPA community.	a) Well-shaded cool canyon bottom. Steep slopes, rim rocks and trees upslope shade area more canopy cover (55 percent) would indicate. Area with moss cover could be at risk from large water flows down canyon. b) Possibly recreation. Very steep, rocky drainage bottom with numerous large moss covered limestone. Many downed trees crossing drainage providing shade No water in drainage.	a) Black Hills National Forest survey form 03R900 - Rubicon East Project b) Black Hills National Forest survey form 03R690D - Rubicon East Project
SD 49 [C]	Approximately 1 mile north of Maurice in Spearfish Canyon on east side of highway.	Black Hills National Forest	27 Jul 2003	One individual occupying approximately 1 m^2.	Midslope (>51percent) with northeast aspect in partial shade in moist soil in BEPA/ PIGL/PIPO community. Somewhat open when trees had fallen. Very steep slope with moss-covered boulders.	Recreational use of the site that has experienced fire. One plant that was shedding seeds was reported; also one reported to be collected. Interesting how many remain.	Black Hills National Forest survey form 03R870 - Rubicon East Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 50 [C]	a) From approximately 0.6 miles south of Spearfish peak plants are approximately 0.55 miles southwest in drainage. b) From approximately 0.6 miles south of Spearfish peak plants are approximately 0.53 miles northwestwest downslope.	Black Hills National Forest	28 Aug 2003	a) 11 to 51 in 2 acres. 20 percent vegetative, 80 percent with seed dispersing. b) 11 to 51 individuals over more than 100 acres. 20 percent vegetative, 80 percent with seed dispersing.	a) In dry-mesic soils at open (40 percent overstory canopy cover) site in PIGL/BEPA/ PIPO to mid slope. b) In dry-mesic soils in shade in OSVI/BEPA/PIPO on bottom of slope.	a) Narrow plant community confined to steep drainage. Birch, spruce dominant with mature pine throughout, but sparse. Scattered uphill from first location but only within drainage. b) Plants scattered down dry drainage. Well shaded within deep steep drainage.	a) Black Hills National Forest survey form 03U450B - Rubicon East Project b) Black Hills National Forest survey form 03U440C - Rubicon East Project
SD 51 [C]	Up steep drainage east of Spearfish Canyon road, approximately 1 mile southwest of Canyon Campground.	Black Hills National Forest	26 Aug 2003	One individual in 5-10 m^2.	In partial shade on 11 to 20 percent incline at bottom of slope on dry-mesic soils in OSVI, BEPA, PIGL, PIPO.	Dry drainage channel with a mix of trees and shrubs and much downed timber. Ironwood-hazelnut most common canopy. *Aquilegia brevistyla* fouund scattered throughout habibat.	Black Hills National Forest survey form 03U340 - Rubicon East Project
SD 52 [C]	1 Jun 1930: Robison Gulch via Spearfish Canyon. 9 Aug 2002: Up Robison Gulch approximately 0.2 miles west of Spearfish Canyon road.	Black Hills National Forest	1 Jun 1930, 9 Aug 2002	9 Aug 2002: 11 to 51 individuals in 1 m^2. All vegetative.	1 Jun 1930: Open mixed woods on shady ledges at 4,200'. 9 Aug 2002: In partial shade in dry soil in PIGL/ACNE2/ BEPA/COCO6 community. Southern aspect. Associated with unidentified fern and *Carex* spp.	9 Aug 2002: Recreation. Steep-deep canyon. Plant on rock face with little soil. Shaded by steep canyons and adjacent canopy. Found throughout survey area in canyon bottom and rocky slopes.	*F.L. Bennett #s.n.* June 1, 1930 Black Hills State University Herbarium. Black Hills National Forest survey form 03R980A - Rubicon East Project August 9, 2002
SD 53	South of Galena, Deadwood South Quad.	Black Hills National Forest	24 Jul 2002	No information.	No information.	No information.	Black Hills National Forest survey form 02RST0 - Row small tracts at Galena Project
SD 54	Deadman Mountain. In a draw north, and on a north facing slope south of FS road 709.1D.	Black Hills National Forest	10 Sep 2002	No information.	Dry mesic soils on north facing slope. Total canopy cover 30-70 percent. With PIPO, POTR5, PIGLD, BEPA.	No information.	Black Hills National Forest survey form 02e250 - Elk Bugs Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 55	Deadman Mtn/Bald Mountain area.	Black Hills National Forest	21 Jun 2000	No information.	Plants in partial shade, north aspect, on a rocky undulating slope at the bottom of a draw. In damp soils. Riparian community type with 45 percent total canopy cover.	No information.	Black Hills National Forest survey form 00CT10 - Centennial Trail Project
SD 56	Along the lower slope of Elk Creek. Deadman Mountain.	Black Hills National Forest	15 Sep 2002	No information.	On lower slope, 5-30 percent incline, of various aspects in dry mesic soil with POTR, PIGLD, PIPO, BEPA, COCO6. 40 percent total canopy cover.	No information.	Black Hills National Forest survey form 02e470 - Elk Bugs Project
SD 57	Little Elk Canyon, Black Hills.	Black Hills National Forest	1924 to 1931	Locally common.	On rocky shaded slopes.	No information.	McIntosh (1931)
SD 58 [D]	South of FSR 172.1 and near the upper reaches of the most southwesterly draw immediately north of FSR 567.1C.	Black Hills National Forest	14 Sep 2002	No information.	On lower slope, variable incline, of various aspects in dry mesic soil on crest-midslope with PIPO and JUCO66. 5 to 80 percent total canopy cover.	No information.	Black Hills National Forest survey form 02e350 - Elk Bugs Project
SD 59 [D]	Along creek bed where creek crosses FS 168.1 road.	Black Hills National Forest	17 Sep 2002	One individual in 1 m^2, with seed dispersing.	Underneath thick OSVI in BEPA/OSVI/PIPO community in dry mesic soils under shade on the bottom of a slope with a 20 percent incline.	No information.	Black Hills National Forest survey form 02K020 - Elk Bugs Project
SD 60 [D]	0.2 miles south of FSR 703.1.	Black Hills National Forest	24 Sep 2002	Seven clumps in 1 m^2 100 percent seed dispersing.	In dry mesic soils in shade with in BEPA-OSVI on bottom of slope.	Growing on large boulder under BEPA.	Black Hills National Forest survey form 02Z330B - Elk Bugs Project
SD 61 [D]	Dry Elk Gulch and drainage approximately 0.5 miles from intersection of FSR 137.1C and FSR 137.1.	Black Hills National Forest	25 Sep 2002	Unknown.	In dry soil at bottom of slope in ACNE2-ULAM-PIGLD/ VETH.	No information.	Black Hills National Forest survey form 02Z360H - Elk Bugs Project
SD 62	Approximately 0.25 miles southwest of intersection of roads 172.1 and 172.1H, population on lower slope in lost Gulch stream bed.	Black Hills National Forest	14 Sep 2002	No information.	Dry mesic soils on creek botton. 350-20 deg aspect. Total canopy cover 20-60 percent. With PIGLD, BEPA, OSVI, COCO6.	No information.	Black Hills National Forest survey form 02e350 - Elk Bugs Project

Table 3 (cont.)

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 63	Approximately 1,600 feet southeast along creek from fork in creek accessible for FSR 171.1C.	Black Hills National Forest	20 Sep 2002	No information.	In mesic soils in PIGL-PIPO-BEPA-OSVI community.	No information.	Black Hills National Forest survey form 02E940F - Elk Bugs Project
SD 64 [E]	Approximately 0.1 miles from Section 19 section line. Plants are approximately 0.15 miles downhill in drainage when water is found.	Black Hills National Forest	1 Oct 2003	One vegetative individual.	In partial shade in moist soils on mid-slope with >51percent incline in BEPA/OSVI/PIPO.	Birch-ironwood deep channel with water, cool and moist. Isolated from cattle use. Very sparse understory.	Black Hills National Forest survey form 03Y370 - Rubicon West Project
SD 65 [E]	Approximately 0.33 miles northwest of the end of road 130.1P.	Black Hills National Forest	31 Aug 2003	11 to 51 in 2 acres.	In moist soil and partial shade with northern aspect at bottom of slope in OSVI/BEPA/ COVO6/PIPO.	Steep north-facing drainage. Moist, moss covered, downed pine trees. Thick litter layer nearby. Soils saturated in drainage channel.	Black Hills National Forest survey form 03U610B - Rubicon West Project
SD 66 [E]	29 Jun 1990: Beaver Creek, north-northeast of Tinton approximately 8 miles west southwest of Spearfish. 5 Sep 2003: a) Approximately 0.9 miles notheast of Soldier Springs. Located on rim rocks at confluence to second drainage draining northwest. b) Northeast of Soldier Spring almost at confluence with dry major drainage.	Black Hills National Forest	29 Jun 1990, 5 Sep 2003	5 Sep 2003: a) Two individual plants in 5 to 10 m^2. One vegetative, one with seed dispersing. b) One to 10 in 5 to 10 m^2. All vegetative.	29 Jun 1990: Base of slope southwest of creek bed with paper birch, hazelnut and spruce at 4,700 feet. 5 Sep 2003: a) In open site on dry soil, north aspect in PIGL/BEPA community. b) Under patial shade on south-facing rock outcrop on ledge at bottom of slope. Dry soil. Birch-spruce-pine habitat near moist drainage.	a) Exposed, only overhead canopy is reflected in 10 sq m plot size. Plants growing on limestone rocks with no direct overhead canopy.	*H.J. Marriott #11275* 1990 RM 2003: a) Black Hills National Forest survey form 03U880A - Rubicon West Project b) Black Hills National Forest survey form 03U890B - Rubicon West Project
SD 67	In a drainage across from an old railroad bed near an archeological site. Approximately 1 mile north from junction between junction between FS roads 144.2 and 226.1.	Black Hills National Forest	13 Aug 2002	No information.	On limestone faces above an old railroad bed, otherwise no information.	No information.	Black Hills National Forest survey form 02W020 - Cavern 6 TSI Project
SD 68	Along Rapid Creek, near Silver City.	Black Hills National Forest, Deerfield Lake and Recreation Area	7 Jun 1960	No information.	Wooded area.	No information.	*T. van Bruggen #4802* SDU

Table 3 (concluded).

State arbitrary number [Occurrence clusters]	Location	Land management/ ownership	Date(s) of observation	Abundance and phenology	Habitat	Other comments	Source[1]
SD 69	Englewood Springs approximately 1.4 miles south of Englewood on Ice Cave Road.	Black Hills National Forest	26 Jul 1983	Infrequent.	In spruce understory with *Oryzopsis asperifolia*, *Rudbeckia hirta*, *Aralia nudicaulis* and *Heracleum* sp.	No information.	*D.J. Ode #83-105* SDU
SD 70	Lower Stagebarn Canyon.	Black Hills National Forest	11 Jun 1924	Frequent.	In stony dry bed.	No information.	*A.C. McIntosh #244* SDU
SD 71	Crook Mountain.	Black Hills National Forest	29 May 1922	No information.	No information.	No information.	*W.H. Over #14291* SDU
SD 72	Rapid Canyon.	Black Hills National Forest	27 Jun 1914	No information.	Wooded hillsides.	Both specimens originally identified *Aquilegia canadensis* and annotated *A. brevistyla*.	*W.H. Over #1568* SDU *B. Lee* (W.H. Over crossed out) *#1568* SDU (appears to be duplicate specimen sheets)
SD 73	Dark Canyon, Rapid City.	Black Hills National Forest or possibly Private	26 Jun 1914	No information.	Thickets and woods.	No information.	*Illegible collector #s.n.* SDU Determined by P.A. Rydberg.
SD 74	Jackass Gulch.	Black Hills National Forest	29 Jun 1973	No information.	Rich wooded north-facing ravine with small stream.	No information.	*K. Hagelstein #s.n.* SDU
SD 75	1928: Box Canon, Lawrence County. 1960: Ice Box canyon.	Black Hills National Forest	30 Jun 1928, 23 Jun 1960	No information.	1928: No information. 1960: Rich woods.	No information.	*W.H. Over #17584* 1928 SDU *T. van Bruggen #s.n.* 1960 SDU
SD 76	“State Park”.	Probably Custer State Park (Wind Cave National Park)	10 Jun 1924	No information.	Creek flood plain.	No information.	*H.E. Lee #B 98* SDU

[1]Herbarium abbreviations (Holmgren and Holmgren 1998):

AUG: Herbarium, Augustana College, Sioux Falls, SD
BHSC: Herbarium, Black Hills State University, Spearfish, SD
CS: Colorado State University Herbarium, Fort Collins, CO
COLO: University of Colorado-Boulder Herbarium, Boulder, CO
FS: Specimen with the USDA Forest Service, Black Hills National Forest, Custer, SD
DWU: Dakota Wesleyan University, Mitchell, SD
KHD: Kathryn Kalmbach Herbarium, Denver Botanic Gardens, Denver, CO
SDU: South Dakota Herbarium, University of South Dakota, Vermillion, SD

Figure 1. Photographs of *Aquilegia brevistyla*. Inserts show close-ups of the flower. Black Hills National Forest staff, used with permission.

are distributed along connecting drainages. These patches may interact through gene flow via seed-dispersal and/or by pollen transfer and therefore may be part of the same interbreeding population. Because the relationships between the known occurrences of *Aquilegia brevistyla* cannot be estimated with the currently available information, an occurrence cannot be equated with a population as defined above. Without knowing the seed dispersal range and specifics of the pollination biology of this species, it is not possible to delineate what comprises a single interbreeding group of plants.

A less restrictive definition of population is that "it is a group of individuals of the same species that occurs in a given area" (Guralnik 1982). Since the genetics of *Aquilegia brevistyla* and the interactions between patches of individuals are unknown, this definition can also be applied to the term "occurrence" as used in this report. The term "population" is used sparingly in this report to denote spatially contiguous groups of plants in large areas, with no genetic implications, or it is used to refer to genetic concerns of *A. brevistyla* or species in general.

Canada and Alaska

Most of the occurrence information for *Aquilegia brevistyla* in Canada and Alaska is derived from herbarium specimens or casual observations by botanists and provides little quantitative information on longevity, abundance, or spatial extent of occurrences (**Table 4**). *Aquilegia brevistyla* is uncommon but relatively widespread through eastern Alaska and western Canada, where it grows in the Northwest Territories, British Columbia, the Yukon Territory, Alberta, Manitoba, Saskatchewan, and east to Ontario (Klinkenberg 2004). This species is apparently most

Figure 2. Illustration of *Aquilegia brevistyla* from Munz (1946); courtesy of the L. H. Bailey Hortorium, Cornell University. Note this illustration is not drawn to a uniform scale. For a size reference, fruits are 15 to 25 mm long and leaflets between 1 and 4 cm long.

frequent in eastern Alaska, the Yukon Territory, the southern third of the Northwest Territories, and the northern halves of Alberta, Manitoba, and Saskatchewan (Whittemore 1997, Klinkenberg 2004). *Aquilegia brevistyla* was reported to be common in the Yukon Valley in southeastern Yukon (Porsild 1951). Occurrence records in British Columbia have been mapped by the British Columbia Data Conservation Center (2004) and can be accessed in E-Flora BC (Klinkenberg 2004). Ten occurrences have been reported from the Hudson Bay Lowlands in northern Ontario (Ontario Natural Heritage Information Center 2004), but no *A. brevistyla* herbarium specimens from Ontario could be located for this report (Meades et al. 2004). Raymond reportedly observed *A. brevistyla* in the James Bay area, Quebec (Scoggan 1978, Porsild and Cody 1980). However, observations of its occurrence in Quebec could not be verified for this report (Waterway personal communication 2005), and the taxon has not been mentioned in regional floras such as Scoggan (1950a) and Gleason and Cronquist (1991). Whittemore (1997) also excludes Quebec from the range of *A. brevistyla*.

In Alaska, *Aquilegia brevistyla* occurrences have been reported from private land and lands managed by the National Park Service, Department of Defense, USFS, and the State of Alaska (**Table 5**). The list of Alaskan occurrences in **Table 5** is incomplete, but it represents examples of the information accompanying readily available specimens from Alaska, such as from the University of Alaska herbarium (ARCTOS 2005) and the literature (Scoggan 1957, Porsild and Cody 1980, Moss and Packer 1983). Several *A. brevistyla* occurrences have been located along or near the Alaska Highway (**Table 4** and **Table 5**). This species has not been reported to be particularly abundant in any area of Alaska or Canada.

Contiguous United States

Within the contiguous United States, *Aquilegia brevistyla* is known to occur in Montana, Wyoming, and South Dakota. These occurrences are significantly disjunct from those areas in Canada where it is most abundant (**Figure 3**), and they may represent colonies that survived in pockets of suitable habitat

Table 4. Summary data for some *Aquilegia brevistyla* occurrences in Canada.

Province	Date observed	Location and management	Habitat, abundance, and comments	Source of information[1]
Alberta	20 Jun 1967	Frenchman's Bay Provincial Recreation Area: French Bay east of peninsula along the Alberta-Saskatchewan border. Cold Lake	Slope of hill -along wood. Several plants flowering and fruiting. Blue-purple plants.	*M. G. Dumais#1231 and G.G. Renkin* TRT
Alberta	11 Jun 1969	McMurray. 20 miles north of town (Athabasca Oil Sands) along the Athabasca River.	Dry bog, stripped woods. Flowering. Note: "Alberta collection #2555 made on 21 June 1968."	*M.G. Dumais #2555a and C. Hufnagel* TRT
Alberta	14 Jun 1972	Kootenay Plains	Aspen/poplar woods at 1,700 m.	*J. Looman #115596* QK
Alberta	26 Jun 1928	Wood Buffalo Park, Mackenzie Basin. Pine Lake district	Open woods, flowering.	*H.M. Raup #2429* TRT
Alberta	20 Jul 1893, 17 Jun 1901, Jul 1903	1893: Banff 1901: Banff, "collected along C.P.R." 1903: Banff	1893: flowering. No information in other years.	*W. Scott #s.n.* 1893 TRT LR *Waldron #344* 1901 COLO. *T. Little #s.n.* 1903 QK
British Columbia	11Jun 1980	Telegraph Creek	On moist creek bank at 305 m. 55 cm high herb. Determined by John Pinder-Moss 1981.	*S. Albright #67* UBC
British Columbia	28 Jun 1979	West bank of Stikine River, 0.5km south of Tsetogamus Creek	Moist mixed forest at 700-772 m.	*W. Gorman #1279* UBC (Stikine-iskut habitat utilization report, BC Hydroelectric & Power)
British Columbia	19 Jun 1932, 21 Jun 1943, 2 Jul 1943	Peace River Land District	No information.	*H.M. Raup and E.C. Abbe* June 19, 1932 CAN 58515 *H.M. Raup and D.S Correll* June 21, 1943 CAN 277629 *H.M. Raup and D.S Correll* July 2, 1943 CAN 277631
British Columbia	22 Jun 1966	Peace River Land District, Muncho Lake	No information.	*G.W. Argus and W.N. Chunys*. June 22, 1966 CAN 309922
British Columbia	21 Jul 1977	Peace River Land District, Wokkpash Lake	No information.	*G.W. Argus and E. Haber* CAN 410471
British Columbia	15 Jun 1960	Alaska Highway, south of Fort Nelson	Occasional in clearing in spruce-aspen woods at 1,600 ft. Flowers blue.	*J.A. Calder and J.M. Gillet #25409* COLO
British Columbia	14 Jul 1956	On road to Meadow lake 8 miles east of Dog Creek Post Office	Occasional along a shady creek bank below cliffs in moist places at approximately 3,000 ft. Flowers blue.	*J.A. Calder, Parmelee and R.L. Taylor #18908* COLO
British Columbia	1925-summer	Cassiar Land District, Dease Lake	No information.	G.W.H. NormanCAN 255104
British Columbia	17 Jul 1928	Horsethief Creek. Near mouth of Horsehead Creek (800 m elevation)	Along stream and meadow. Rare. Flowering.	*U. Titus #1159* TRT
Manitoba	19 Jul 1950	Gillam	Dry sandy soil on hilltop. Rare.	*W.B. Schofield #1201* COLO
Manitoba	6 Jul 1955	MacBride River area	On steep slope of loamy soil with S. aspect, shoreline. Flowering and fruiting.	*J.C. Ritchie #1086* TRT
Manitoba	7 Jul 1955	MacBride River area	Open prairie-like vegetation of post-burning phase. Rare. Flowering.	*J.C. Ritchie #1131* TRT
Manitoba	1 Jul 1979	Riding Mountain National Park. East side of Clear Lake at Wasagming	Wooded slope leading down to lake, flowering.	*W.J. Cody #23870* and *W.A. Wojtas* TRT
Manitoba	14 Jun 1933	Riding Mountains	No information.	*B.J. Hales #s.n.* COLO

Table 4 (concluded).

Province	Date observed	Location and management	Habitat, abundance, and comments	Source of information[1]
Northwest Territories	19 Jun 1950	McKenzie District, Fort Smith	In sand by roadside at edge of *Pinus banksiana-Populus tremuloides* woods. Flowers blue-purplish. Rare.	*W.J. Cody and C.C. Loan #3881* COLO
Northwest Territories	14 Jul 1939	McKenzie District, vicinity of Brintell, south slope of Red Mountain, west of lake	Dry water-course in granite rock. Flowers pale purple, centers creamy white.	*H.M. Raup and J.H. Soper #9473* COLO
Northwest Territories	19 Aug 1993	Mackenzie District, Mile 36 Canol Trail at Pump Station 2	Disturbed area in limestone river canyon.	*W.T. Dushenko #s.n.* QK
Saskatchewan	17 Jun 1964	Mouth of Clearsand Creek	Sand with *Salix* and grasses.	*J.K. Jeglum #77-64* SSMF
Saskatchewan	22 Jun 2002	Duck Mountain Provincial Park	No information.	Colin Ladyka, website: http: //www.colinherb.com/
Saskatchewan	21 Jun 1936	Prince Albert National Park	Muskeg, flowering.	*E.T. Howe #s.n.* TRT
Saskatchewan	17 Jun 1944	Prince Albert National Park: Crean Lake	Sandy soil between woods and lake. Flowering and fruiting.	*R.C. Russell #s.n.* TRT
Saskatchewan	5 Aug 1966	Meadow Lake Provincial park	On rich soil along old trail through heavy poplar woods.	*J.H. Hudson #2477* COLO
Saskatchewan	16 Jun 1949	District of Melfort, Candle Lake	Upper rocky beach at edge of forest.	*Brown and Breitung #6001* COLO
Saskatchewan	27 Jul 1979	Clearwater River, approximately 0.5 to 1 km north of Smoothrock Falls approximately 2 km southwest of Gould Rapids	On rock outcrops, under open Jack pine woods.	*V.L. Harms and R. Wright #26033* COLO
Saskatchewan	11 Jun 1972	Mile 7 on Highway 155, 7 miles north of Green Lake	Aspen/poplar wooded area along small creek tributary of Beaver River. Common locally.	*V.L. Harms #18737* COLO
Yukon	23 Jun 1944	Vicinity of Pine Creek near mile 1019 Alaska Highway	Thickets and open woods.	*H.M. and L.G. Raup #11865* COLO
Yukon	23 Jun 1949	Dawson, town center.	Along moist banks of roadside and in abandoned fields. Flowers purple-white. Rather rare.	*J.A. Calders and L.G. Billard #3256* COLO
Yukon	27 Jun 1949	Along Alaska Highway, south of Whiteham	Roadside. Petals greenish-white and spurs blue. Occasional.	*J.M. Gillett #3517* COLO
Yukon	8 Jun 1995	La Biche River	Roadside with Picea sp. and Betula papyrifera. Represents extension of range by 175 km to the east.	*W.B. Bennett #95-134* DAO (Cody et al. 1998)
Yukon	16 Jun 1997	Meadow by roadside to Upper Gaswell	Meadow; represents extension of range by 175 km to the east.	*W.B. Bennett #97-195* DAO (Cody et al. 1998)
Yukon	2 Jul 2000	Kluane National Park and Reserve. Old Experimental Farm and Park Headquarters	No information.	*P. Caswell #189* ALA
Yukon	Jul 2002	Quiet Lake, South Canoe Road	Duplicate specimens.	*C. Latimer #126* UBC
Not reported	16 Jun 1885	Morley, foothills of Rocky Mountains	Dry thickets.	*J. Macoun #s.n.* Collection as part of Geological survey.

[1]Herbarium abbreviations (Holmgren and Holmgren 1998):

ALA: University of Alaska Museum, Herbarium (ARCTOS 2005), Fairbanks, Alaska, USA

CAN: Canadian Museum of Nature, Ottawa, Ontario, Canada

DAO: Agriculture and Agri-Food Canada, , Ottawa, Ontario, Canada

COLO: University of Colorado Herbarium, Boulder, Colorado, USA

TRT: Green Plant Herbarium of the Royal Ontario Museum, Ontario, Canada

UBC: Herbarium, Botany Department, University of British Columbia, Vancouver, British Columbia

QK: Fowler Herbarium (2005), Department of Biology, Queen's University, Kingston, Ontario, Canada

SSMF: Great Lakes Forestry Centre Herbarium, Canadian Forest Service; Information from the Northern Ontario Plant Database Office

Table 5. Summary data for some *Aquilegia brevistyla* occurrences in Alaska (Holmgren and Holmgren 1998).

Observation date	Land management	Location	Source[1] of information	Habitat and comments
26 Jun 1941	Unknown	Eklutna	*J.P. Anderson #6938* COLO	Rocky soil.
13 Jun 1983	Chugach State Park	Eklutna Valley	*L.C. Marvin #671* ALA	Southeast slope, aspen community.
9 Jul 1949	Unknown	Little Susitna River	*G.M. Frohne #49* 19148 COLO	No information. Determined by C.L. Porter.
26 Jun 1949	Unknown	Little Susitna River northeast of Palmer	*G. M. Frohne #49-107* ALA	No information.
21 Jun 1951	USDA Forest Service	On beaches of the Matanuska River 2.9 miles above Granite Creek 17 miles from Palmer, Alaska	*H.J. Lutz #102335* COLO	An old stand of balsam cottonwood and white spruce. Rare. Determined by WA Dayton; duplicate in Forest Service Herbarium, Palmer Alaska.
30 Jul 1964	Unknown	Shaw Creek Flats, Richardson Highway	*L.A. Viereck # 7222* COLO	*Astragalus* and *Oxytropis* and roadside weeds. 950 feet on a flat slope. Very abundant in a few localities; common blue-flower herb. Duplicate in Forest Service Herbarium, Alaska.
13 Jul 1998	Fort Greely Military Reservation	Alaska Range, 33 mile Loop Road E of Eddy DZ 1 &2	*M. Duffy #98-134* ALA	Disturbed edge of aspen-spruce muskeg, occasional on heavy clay soils with thin organic layer, with *Shepherdi* and *Salix* spp.
26 Jul 1978	Unknown	Eagle Bluff	*A. Batten and J.C. Dawe #78-365* ALA	Swale in steep southwest-facing slope, with pop
31 Jul 1957	Unknown	Gerstle River	*L.A. Spetzman* ALA	Wooded dunes near sawmill
12 Jul 1964, 12 July 1968	Unknown	1964: Glenn Highway at Hicks Creek. 1968: Glen Highway on Tok Cutoff about mile 87 from Gakona Junction	*M. Williams #763* 1964 ALA; *M. Williams #2431* 1964 CHSC	1964: No information. | 1968: Steep, man-made gravel bank.
10 Jul 1976	Unknown	Glenn Highway, near Matanuska Glen Campground, mile 101	*T. Ward #s.n.* ALA	Paper birch forest, moist soils
10 Jul 1976	Unknown	Matanuska Valley, Long Lake, Glenn Hwy	*L.L. Hawkins #128* ALA	South-facing slope with aspen
09 Jul 1998	Wrangell-St. Elias National Park and Preserve	Mentasta Mts., Punk Lake, between Platinum and Totschunda Cr., slope N of lake	*A. Batten #98-21* ALA	Opening in *Populus balsamifera-Salix bebbiana* woodland, with *Calamagrostis purpurascens* and *Epilobium angustifolium*
04 Sep 1988	Unknown	Salcha River, 12 km upstream from mile 323.1 Richardson Hwy	*J.R. Grant #88-138* ALA	No information.
02 Aug 1995	Fort Wainwright Military Reservation	Tanana Lowlands, escarpment 10 km east-southeast of Blair Lakes	*M. Duffy and M.K. Raynolds #95-835* ALA	Scrubby wooded gully, on strongly sloping southeast-facing upper slope
20 Jul 1927	Unknown	Tanana Lowlands, Fairbanks	*L.J. Palmer #1824* ALA	No information
24 Jun 1986	Unknown	Tanana Valley, Mile 1361 Alaska Hwy, Dot Lake, near lodge	*R. Lee #86-37* ALA	No information

Table 5 (concluded).

Observation date	Land management	Location	Source[1] of information	Habitat and comments
28 Jun 1927, 30 Jun 1964	Unknown	28 Jun 1927: Tanana Valley, Richardson Hwy., Mile 295, Richardson Roadhouse. 30 Jun 1964 : Tanana Lowlands, Richardson Hwy., Mile 287 Shaw Cr.,flats	*L.J. Palmer #2005* 28 Jun 1927 ALA; *L.A. Viereck #7222* 30 Jun 1964 ALA	30 Jun 1964: disturbed soil, flat, weeds
01 Aug 1963	Unknown	Tanana Valley, upper Tanana River, above Gerstle River	*L.A. Viereck #963* ALA	Flood plain, flat
1 Aug 1963	Unknown	Flood plain of the Tanana River near the mouth of the Gerstle River	*L.A. Viereck #7038* COLO	In an area that received frequent flooding. At 1,200 feet on a flat slope in river alluvium with *Populus balsamifera* and *Eleagnus commutata*. Rare in abundance. Perennial 3 feet high; blue flower.
29 Jul 1965, 22 Jun 1968	Unknown	29 Jul 1965 : Yukon-Tanana Uplands, Elliott Hwy. Mi 28 , Snowshoe Pass, Wickersham Dome 22 Jun 1968 : Yukon-Tanana Upland, Elliott Hwy, Mi 39	*V.L. Harms #4515* 29 Jul 1965 ALA; *J.M. Leon and J.A. Dunker #8* 22 Jun 1968 ALA	29 Jul 1965: dry gravelly rocky open area. 22 Jun 1968: on steep bank by road
12 Jul 1949	Unknown	Yukon-Tanana Uplands, Richardson Hwy .Mile 306, Birch Lake, 63 miles S of Fairbanks	*Juneau Botanical Club #845* ALA	No information

[1]Herbarium abbreviations:

ALA: University of Alaska Museum, Fairbanks, Alaska, USA
CAN: Canadian Museum of Nature, Ottawa, Ontario, Canada
CHSC: Biological Sciences Herbarium, California State University – Chico, Chico, California, USA
DAO: Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada
COLO: University of Colorado Herbarium, Boulder, Colorado, USA
TRT: Green Plant Herbarium of the Royal Ontario Museum, Ontario, Canada
UBC: Herbarium, Botany Department, University of British Columbia, Vancouver, British Columbia
QK: The Fowler Herbarium, Department of Biology, Queens University, Kingston, Ontario, Canada
SSMF: Great Lakes Forestry Centre Herbarium, Canadian Forest Service; information from the Northern Ontario Plant Database Office

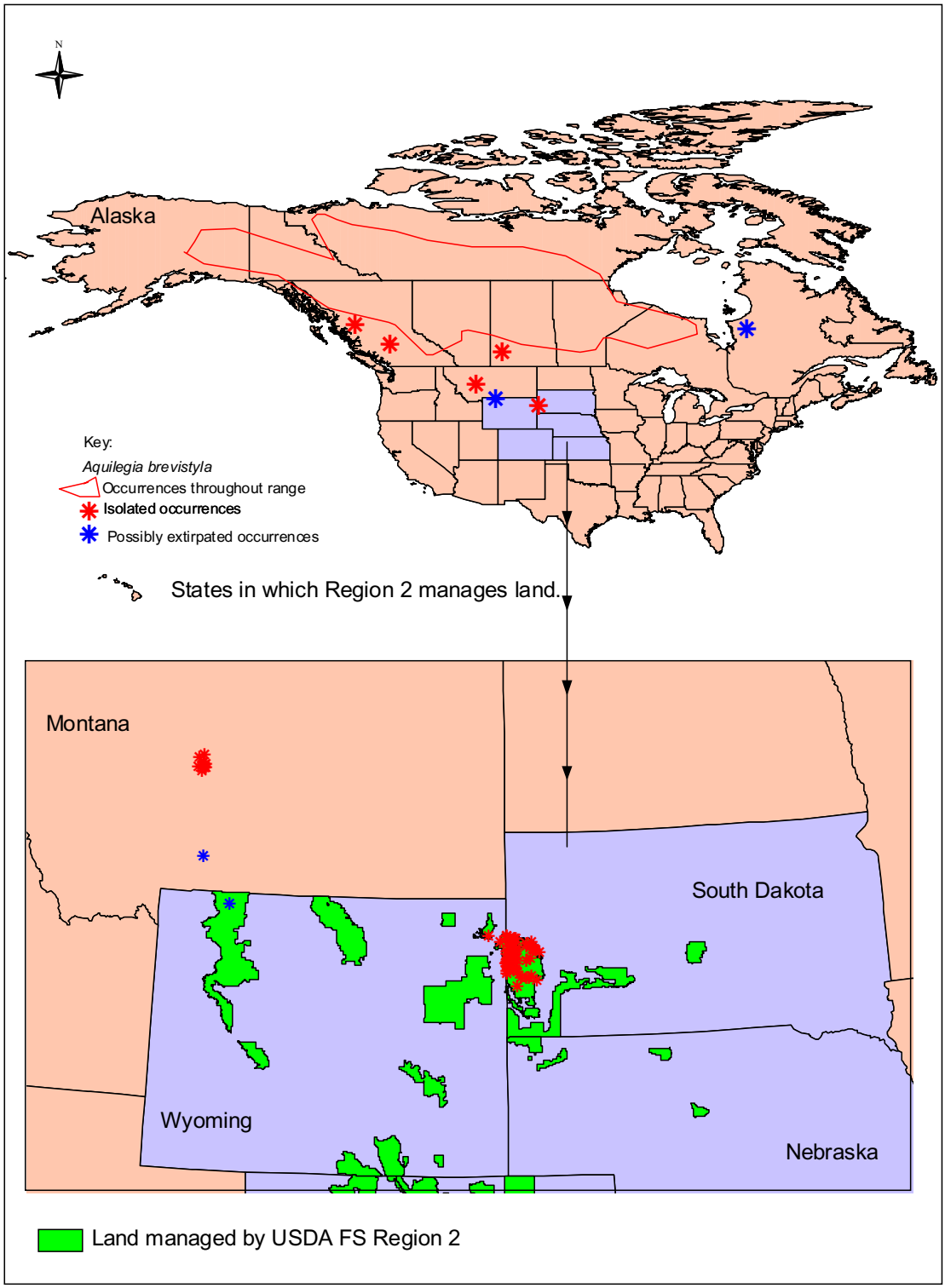

Figure 3. Global range of *Aquilegia brevistyla*.

as temperatures rose relatively rapidly at the end of Wisconsin glaciation approximately 10,000 years ago (Daubenmire 1978, Davis 2003). *Aquilegia brevistyla* is one of several disjunct boreal species in the Black Hills of South Dakota and Wyoming (Barr 1983, Marriott 1985).

Montana

Except for one observation in Sweetwater County in 1967 and an unverified report from Glacier County (Lesica et al. 1984), all known occurrences of *Aquilegia brevistyla* in Montana are located on the Lewis and Clark National Forest in Judith Basin County (**Table 1**). *Aquilegia brevistyla* is not abundant on the Lewis and Clark National Forest but may be locally common. Occurrence sizes range from two to more than 2,000 stems. The location of the 1967 record (MT1 in **Table 1**) may have been from private or National Forest System land. The specimen that documents this occurrence was pressed in such a way as to prevent critical measurements of the flower (Mathews 1989), and it may actually be *A. coerula* although this taxon has not been observed in the area (Mathews 1989). The specimen may be a hybrid since Lesica and Shelly (1991) noted that hybrids between *A. jonesii* and *A. flavescens* have been mistaken for *A. brevistyla* in Montana.

Wyoming and South Dakota

More than 96 percent of the known *Aquilegia brevistyla* occurrences in Region 2 (Wyoming and South Dakota) are on National Forest System land (**Table 3**). One historic *A. brevistyla* occurrence was reported from the Shoshone National Forest in Wyoming (WY 1 in **Table 3**), but no plants have been found there since 1924 (Wyoming Natural Diversity Database 2004). Another collection made at the same time but with no collection number was deposited at the Rocky Mountain herbarium by D. and E. Pearson (#s.n., Park Co. collected 7/21/1924 RM). This specimen was initially identified as *A. flavescens* but, in 1966, C.L. Porter commented on the specimen sheet that it might be a hybrid between *A. flavescens* and *A. formosa*. The specimen was later annotated as closest to *A. brevistyla* but with the spur being [atypically] a little long" by R. Dorn in 1987. Other occurrences in Wyoming (WY 2 and 3 in **Table 3**) extend over lands managed by the Black Hills National Forest and the BLM Newcastle Field Office. In South Dakota, *A. brevistyla* has been reported from the Wind Cave National Park and the "State Park," probably the Custer State Park (SD 75 in **Table 3**). The land management of two occurrences are not known (SD-31 and SD 37 in **Table 3**) and one other occurrence may be either on land managed by the NPS or on NFS land (SD-1 in **Table 3**). All other occurrences in Wyoming and South Dakota are on the Black Hills National Forest (**Table 3**).

In Region 2, as elsewhere, occurrence sizes of *Aquilegia brevistyla* appear to be highly variable. *Aquilegia brevistyla* plants may be scattered singly, in small patches of fewer than a dozen individuals, or locally abundant (**Table 1**, **Table 3**). Density is also variable; for example, six stems occupy 1 m^2 at one occurrence but are distributed over 25 m^2 at another occurrence. Twenty-five out of 90 observations reported by USFS personnel on the Black Hills National Forest between 2001 and 2004 contained between one and five individuals or stems (**Table 3**). An observation of so few stems indicates that there were no other individuals within sight at the time they were observed. However, because of their proximity or spatial relationship to other observations, these individuals or small patches may be what the NatureServe (2004b) system designates as sub-occurrences.

NatureServe (2004b) encourages the development of taxon-specific specifications to delineate an occurrence. However, in the absence of such specifications, they suggest combining patches of plants that either grow within 1 km of each other, or grow within 3 km of each other if there are no stretches of persistently unsuitable habitat longer that 1 km between them, or grow within 10 km of each other and share a linear riparian system with no areas of persistently unsuitable habitat longer than 3 km between them. A detailed description and decision-tree for making occurrence delineations are provided on the NatureServe website (NatureServe 2004b). NatureServe's guidelines have been followed as much as possible in this report, and when the specificity of location information permits, patches or individuals that are spatially close to each other or distributed down interlinked drainages are referred to as sub-occurrences and combined in **Table 1** and **Table 3**. This method, which provides a conservative estimate of the number of known occurrences, was used in this assessment because of the frequency with which only a few or single plants were reported at an occurrence.

Using the NatureServe approach is one possible method of interpreting the available information. The number of occurrences is frequently used to evaluate the vulnerability of a taxon, and it is debatable whether an occurrence consisting of three plants can be given the same weight as one including 300 plants. A greater understanding of the biology and ecology of the taxon,

further analysis of the existing data, and/or additional field observations may change the concept of occurrence sizes, patterns, or numbers.

On the Black Hills National Forest, approximately 90 *Aquilegia brevistyla* observations (not all at distinctly different locations) were documented between 2001 and 2005. Either direct counts or range estimates of abundance (e.g., "1 to 10 plants" or "101 to 500 plants") were reported for 85 observations. Range estimates are often employed when time for more detailed surveys is limited. However, statistically valid estimates of the total number of plants and the "average number" of plants per occurrence are very difficult to make using range estimates. Using the available *A. brevistyla* data and the mid-point of each range estimate, the estimated total of plants in the Black Hills is 5,979. If the minimum number of each range is used, then this number decreases to 3,300, and if the maximum number of each range is used, the estimated total increases to 8,659. Although the mid-point value is sometimes considered more reliable than any other value, its use obscures the uncertainty associated with the estimate. Statistically there is no greater likelihood that the mid-point reflects the true number of plants better than any other number within the range. It is reasonable to conclude that the total population of *A. brevistyla* in Region 2 falls between 3,300 and 8,659 plants.

Generating meaningful numbers to summarize an "average" occurrence size is even more difficult using only range values. Using the mid-point value of the range estimated at each site in Region 2, there would be an average of 71 individuals per occurrence (n = 85; SD = 117)[1]. However, in this case, considering "the average" number of individuals per occurrence is likely to be misleading since 67 percent (57 out of 85) occurrences had less than a range maximum of 51 plants per observation and 40 percent (34 out of 85) had fewer than 13 plants per observation, both of which are significantly less than the estimated 71 plants per occurrence. An additional consideration in estimating the total number of individuals within an area is the potential for multi-stemmed individuals. In general, from the surveyors' notes it appears that the number of stems observed at an occurrence has been reported. If individual plants have multiple stems, the estimate of the total number of individuals needs to be adjusted accordingly (see Reproductive biology and autecology section for the potential consequences of inaccurately estimating the number of individuals).

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or within the network of Data Conservation Centers and Natural Heritage Programs to determine long-term population trends for *Aquilegia brevistyla*. This taxon has been collected relatively infrequently, and no occurrences have been monitored in any part of its range. Most *A. brevistyla* occurrence locations in Canada and Alaska, such as those mapped in Porsild and Cody (1980), cannot be confirmed as extant because they have not been visited in more than 20 years. Recent observations indicate that the taxon is persistent at some sites, but no evaluation can be made of its current status compared to its historic abundance and distribution.

Within the contiguous United States, the distribution of *Aquilegia brevistyla* appears to be restricted to Judith Basin County in Montana and to the Black Hills in South Dakota and Wyoming. Current information suggests that plants are abundant in these areas, but historic records of its abundance are lacking. Records do not exist to assess whether this species is more or less abundant than it was prior to European settlement, which caused substantial modification to Black Hills habitats (Marriott et al. 1999). *Aquilegia brevistyla* appears to have been found consistently, but at a low frequency, for more than a century at several sites in the Black Hills (**Table 3**). It was found "near Spearfish" in 1902 (SD 39 in **Table 3**) and at Rochford in 1897 (SD 26 in **Table 3**), and it was especially frequent in the Spearfish Canyon/Spearfish Creek regions (McIntosh 1931). Many recent observations have also been reported from this area, which extends approximately 31 km south of the city of Spearfish in the Black Hills National Forest (**Table 3**). The large number of *A. brevistyla* observations in the Black Hills National Forest made in the last three years, and especially in 2004, may not represent a true increase in abundance but only an increase in awareness for the species since it was targeted for survey (**Table 3**). Another possibility is that the increased number of plants observed during recent surveys represents a true increase in abundance. A third alternative is that *A. brevistyla* occurrences naturally fluctuate in size and extent over time; periods

[1]Using the minimum value of the range at each site there is an average of 39 individuals/occurrence, and standard deviation of the mean of the 85 observations (std.) of 65. Using the maximum value there is an average of 103 individuals/occurrence, with a std. of 177.

of high abundance may be followed by phases when numbers are low and the range contracts.

At several sites in South Dakota and Montana, only historic records of *Aquilegia brevistyla* exist (**Table 3**), and these may no longer be extant. Wind Cave National Park includes areas with suitable habitat for *A. brevistyla*, but despite several targeted surveys, no plants have been observed since 1966, at which time no specimens were collected. There was no information available about abundance or location in 1966 (Curtin personal communication 2004). The *A. brevistyla* occurrence found by Thornton in 1967 near Boulder Creek in or near the Gallatin National Forest (MT1 in **Table 1**) has not been relocated despite intensive searches that encompassed suitable habitat in parts of approximately 99 sections around the original site (Montana Natural Heritage Program 2004). Firewood cutting and heavy recreational use of Boulder Creek have led to significant habitat modification (Mathews 1989). An *A. brevistyla* occurrence reported from the Shoshone National Forest has not been relocated since 1924 (Fertig 1998, Wyoming Natural Diversity Database 2005). Fertig (2001) suggested that this record might refer to a hybrid individual involving *A. flavescens*, *A. formosa*, or *A. brevistyla*.

Habitat

Aquilegia brevistyla grows in the montane zone between 1,250 and 2,140 m elevation in the Black Hills (Region 2). In Montana, it has been found between 1,524 and 1,890 m, with one unverified report above 3,000 m. In Canada and Alaska, *A. brevistyla* has been observed between 490 and 2,800 m.

Rangewide, *Aquilegia brevistyla* has been reported to grow in the understory of coniferous forests and open woods, in mesic meadows, on rock outcrops, and on flats and shores along rivers and streams (Whittemore 1997). It is most frequently reported from mesic habitats but has been reported to grow in drier sites. The circumstances when this occurs, however, have not been defined. Local factors such as the aspect and extent of shade cover may influence the degree to which drier soils provide habitat.

Prior to the targeted surveys in the early 2000's, *Aquilegia brevistyla* appeared to be restricted to riparian habitats in the Black Hills of Wyoming and South Dakota (Kratz 2005). It now appears that this species is most often associated with mesic conditions under *Picea glauca* (white spruce) (**Table 3**). Occurrences in the Black Hills have also been documented in mesic *Pinus ponderosa* (ponderosa pine) and hardwood woodlands (Kratz 2005). Within the coniferous and hardwood community types, *A. brevistyla* occurrences are often observed on or below limestone rock outcrops, in boulder microsites, and in dry ephemeral streambeds (Kratz 2005).

Soils

Aquilegia brevistyla is frequently found on calcareous soils and limestone rock outcrops (**Table 1**, **Table 3**, **Table 5**), suggesting that it may be restricted to calcareous substrates in South Dakota (Ode personal communication 2003). Certainly it appears more abundant where the soil is likely to be calcareous (e.g., SD 15, 18, 20, 31, 37, 38, 41, 43, 45, 48, 68 and WY 4 in **Table 3**). In southeastern Yukon, *A. brevistyla* was common on calcareous shales on riverbanks from White Horse to the Pelly River (three specimens collected), but it was not seen elsewhere even though it had been reported to be common in the Yukon Valley (Porsild 1951). The taxon may not be a true calciophile, however, since it has also been found in organic soils and in gravels derived from granitic parent material. Occurrences near Deerfield Recreation Area near Oreville (SD 31 and 68 in **Table 3**) and in the Bloody Gulch area (SD 24 in **Table 3**) are located on the Central Crystalline Core of the Black Hills, where the soils are derived from Precambrian granite, pegmatite, and metasedimentary rocks (South Dakota School of Mines and Technology 2004, Nationalatlas.gov 2005). Although granitic soils may not necessarily have a low pH, they are very susceptible to acidification. This apparent variation in habitat soil conditions suggests that there might be ecotypes that differ with respect to a requirement for calcareous environments.

Slope and aspect

Occurrences of *Aquilegia brevistyla* have been reported on slopes of between 0 and greater than 51 percent in British Columbia (Klinkenberg 2004). In the Black Hills, plants have been found on essentially level areas to slopes greater than 60 percent and on vertical rock faces. Often found near the base of boulders on the canyon sides and floor, *A. brevistyla* also grows on seep-fed and dry-mesic rocky ledges on steep slopes in the Black Hills (**Table 3**). However, even though vertical slopes have been described as providing habitat, the plant typically grows on rocky ledges, and the microhabitat incline that the plants actually experience may be level or very gentle.

In the Black Hills, *Aquilegia brevistyla* occurrences typically have a northerly aspect. Aspects ranged from 310 to 50 degrees for 62 of 78 occurrences where aspect was reported. This is consistent with observations in Wyoming and Montana. At one occurrence in the Black Hills where *A. brevistyla* was reported from a west aspect, it was noted that the micro aspect (secondary aspect) was 5 degrees. Only two observations indicated that occurrences had a southern exposure (SD 52 and SD 66b in **Table 3**). All plants were vegetative at these sites, and the occurrences need to be revisited when plants are in their reproductive phase for species confirmation.

Moisture

The U.S. Fish and Wildlife Service (1988) has not assigned *Aquilegia brevistyla* a wetland indicator status. This species grows in shade and partial shade, most commonly on lower and mid slopes, in side drainages, and within the riparian zone of perennial streams (**Table 1**, **Table 3**). It also frequently grows along the edges of active channels of perennial streams that may be entrenched (Rosgen 1994). While moist or mesic conditions appear to be a common requirement, the taxon does not appear to depend on permanently moist conditions. In British Columbia, occurrences usually are in mesic soils (Klinkenberg 2004). Mesic soils are those where water is removed fairly slowly in relation to supply, and they may remain moist for a significant, if sometimes short, period of the year. The driest conditions in which *A. brevistyla* has been found in British Columbia are subxeric (Klinkenberg 2004). In subxeric soils, water is removed rapidly in relation to supply, and the soil is moist for only short periods following precipitation. The wettest conditions recorded for *A. brevistyla* habitat in British Columbia are hygric, where water is removed slowly enough to keep soil wet for most of growing season and the primary water source is permanent seepage (Klinkenberg 2004).

In the Black Hills National Forest, *Aquilegia brevistyla* plants have mostly been located in dry-mesic, mesic, and moist sites, with most observations being in mesic sites (**Table 3**). Dry-mesic sites usually refer to those with well-drained soils (White and Lloyd 1998). It is not clear whether moist conditions refer to hygric soils. Because a number of observers collected the occurrence records, it is possible that the terms were not applied consistently. Inconsistencies in habitat descriptors may suggest that *A. brevistyla* is tolerant of either a narrower or a wider range of environmental conditions than is actually the case. Three observations have been made of *A. brevistyla* plants at dry sites (SD 17, 52, and 61 in **Table 3**). At one of these sites (SD 17 in **Table 3**), two individuals were found growing on north-facing limestone rocks with no direct overhead canopy. At the second site (SD 52 in **Table 3**), the occurrence had a southern exposure, and all the individuals were vegetative. At the remaining site (SD 61 in **Table 3**), plants were reported to be in dry soil, but no details of their reproductive status or abundance were given.

Vegetation community

In Canada and Alaska, *Aquilegia brevistyla* is principally found in coniferous forests. In British Columbia, it grows in the Boreal White and Black Spruce biogeoclimatic zones and occurs in Engelmann Spruce – Subalpine Fir, Interior Douglas-fir, Sub-Boreal Pine–Spruce, and Sub-Boreal Spruce communities (Klinkenberg 2004). In Montana, *A. brevistyla* is described from open woods and stream banks at mid-elevations in the montane zone (Mathews 1989, Roe 1992); the available occurrence records suggest that *Picea englemannii* (Engelmann spruce) is always a community member (**Table 1**).

In the Black Hills of Wyoming and South Dakota, *Aquilegia brevistyla* is found in *Picea glauca*, *Pinus ponderosa*, *Populus tremuloides* (aspen), and less frequently, in hardwood forest associations (**Table 3**, **Figure 4**, **Figure 5**; USDA Forest Service 2003a). The Black Hills region supports the most western occurrence of *Picea glauca* in the United States (Shepperd and Battaglia 2002). These forests are a significant component of high-elevation coniferous forests in the Black Hills where temperatures are cooler and precipitation is greatest (Marriott et al. 1999, Shepperd and Battaglia 2002). Common seral species in these forests include *Pinus ponderosa*, *Populus tremuloides*, and *Betula papyrifera* (paper birch) (Hoffman and Alexander 1987). Two *Picea glauca* community types occur in the Black Hills: the *Picea glauca/Linnaea borealis* (white spruce/twinflower) association and the *Picea glauca/Vaccinium scoparium* (white spruce/grouseberry) association (Hoffman and Alexander 1987, Marriott and Faber-Langendoen 2000a). The *Picea glauca/Linnaea borealis* association is usually found on northwest to northeast aspects and is distinguished from the other association by the abundance of *Linnaea borealis* (twinflower) and the absence of *Vaccinium scoparium* (grouseberry) in the understory (Shepperd and Battaglia 2002). Mosses and lichens are also abundant in this association (Hoffman and Alexander 1987). The other community type,

Figure 4. Photograph of *Aquilegia brevistyla* plants in flower. Black Hills National Forest staff, used with permission.

Picea glauca/Vaccinium scoparium, is distinguished by the presence of *V. scoparium* in the understory, but its coverage can be variable (Shepperd and Battaglia 2002). *Aquilegia brevistyla* occurs in both associations with similar frequency (**Table 3**). *Picea glauca/Linnaea borealis* and *Picea glauca/Vaccinium scoparium* forests grow in soils derived from both limestone and igneous parent material, and occur in more mesic habitats on the Limestone Plateau and in the Central Crystalline Core (Marriott et al. 1999). Both communities are absent from the Bear Lodge Mountains (WY 4 in **Table 3**), even at comparable elevations (Marriott et al. 1999). Habitat requirements of *A. brevistyla* occurrences in Montana and those in the Black Hills might be similar since the dominant tree species in both geographic areas (*P. glauca* in the Black Hills; *P. engelmannii* in Montana) share many of the same silvicultural and ecological characteristics (Shepperd and Battaglia 2002).

The plant species found with *Aquilegia brevistyla* in South Dakota, Wyoming, and Montana are listed in **Table 6**. Differences between plant species associated with *A. brevistyla* in Canada and in the Black

Figure 5. Photographs of coniferous forest (above) and aspen woodland (below) habitats on the Black Hills National Forest that contain *Aquilegia brevistyla*. Black Hills National Forest staff, used with permission.

Table 6. Plant species associated with *Aquilegia brevistyla* in South Dakota, Wyoming, and Montana. This is not a complete list because it includes only the species mentioned on herbarium sheets, in the literature, or on field observation forms. The associated mosses in particular have not been well described. Abbreviations are those published by USDA Natural Resources Conservation Service (2002).

Taxon	Abbreviation[1]	Taxon	Abbreviation[1]
Picea glauca	PIGL	*Juncus compressus*	JUCO
Pinus ponderosa	PIPO	*Juniperus communis*	JUCO6
Betula papyrifera	BEPA	*Koeleria macrantha*	KOMA
Populus tremuloides	POTR5	*Lathyrus ochroleucus*	LAOC2
Acer negundo	ACNE2	*Linnaea borealis*	LIBO3
Achillea millefolium	ACMI2	*Lonicera dioica*	LODI2
Aconitum columbianum	ACCO4	*Lupinus argenteus*	LUAR3
Actaea rubra	ACRU2	*Mahonia repens*	MARE11
Agrimonia striata	AGST	*Maianthemum stellatum*	MAST4
Agrostis stolonifera	AGST2	*Moehringia lateriflora*	MOLA6
Anemone multifida	ANMU	*Orthilia secunda*	ORSE
Aquilegia brevistyla	AQBR	*Oryzopsis asperifolia*	ORAS
Aralia nudicaulis	ARNU2	*Osmorhiza longistylis*	OSLO
Arnica cordifolia	ARCO9	*Poa pratensis*	POPR
Berberis repens	BERE	*Prunus pensylvanica*	PRPE2
Brickellia incana	BRIN	*Prunus virginiana*	PRVI
Bromus ciliatus	BRCI2	*Pyrola asarifolia*	PYAS
Bromus sp.	BROMUSSP	*Pyrola* sp.	PYROL
Carex deweyana	CADE9	*Rosa acicularis*	ROAC
Carex sp.	CAREX	*Rosa* sp.	ROSASP
Clematis columbiana	CLCOT	*Rubus idaeus*	RUID
Cornus sericea	COSES	*Sanicula marilandica*	SAMA2
Cynoglossum officinale	CYOF	*Schizachne purpurascens*	SCPU
Disporum trachycarpum	DITR2	*Smilacina stellata*	SMST
Elatine triandra	ELTR	*Spiraea betulifolia*	SPBE2
Festuca sp.	FESTU	*Symphoricarpos albus*	SYAL
Fragaria virginiana	FRVI	*Tortella rigens*	TORI (moss)
Frasera speciosa	FRSP	*Urtica dioica*	URDI
Galium bolanderi	GABO	*Viburnum* sp.	VINUC
Galium boreale	GABO2	*Vicia americana*	VIAM
Galium trifidum	GATR2	*Viola adunca*	VIAD
Galium triflorum	GATR3	*Viola canadensis*	VICA4
Geranium richardsonii	GERI	*Viola* sp.	VIOLA
Halenia deflexa	HADE2	*Zizia aptera*	ZIAP
Hylocomium splendens	--------		

[1]Notes:

ACMI2 (reported as ACMI)

ACRU2 (reported in notes as ACRV2)

No name was found in the USDA PLANTS database to be associated with the species listed on the field survey forms as: PBE2, DIRT2, VICA

Hills/Judith Basin County areas are likely to reflect community differences related to latitude; species reported only from occurrences outside of Regions 1 and 2 have not been included. The abbreviation, VICA, was used to describe an associate of *A. brevistyla*. VICA denotes *Viburnum cassinoides* (syn: *V. nudum* var. *cassinoides*), which is a sensitive plant species restricted to the East Coast of the United States (USDA Natural Resources Conservation Service 2002). This abbreviation is therefore likely to be a typing error and actually refers to *Viola canadensis* (VICA4; USDA Natural Resources Conservation Service 2002).

Cover at occurrences in the Black Hills

Aquilegia brevistyla typically grows in areas with an overstory canopy cover of more than 30 percent, but very occasionally it grows without any overhead tree canopy. Habitat descriptions of these open canopy sites suggest that geological formations may provide shady conditions. At *A. brevistyla* sites in the Black Hills, tree canopy cover ranged from zero to 100 percent, shrub cover from 0 to 60 percent, and forb cover from 1 to 80 percent (Black Hills National Forest survey records). Grasses and graminoids were typically a relatively small component of the community and rarely reach 10 percent canopy cover. At one site, however, grass/graminoid canopy cover was 40 percent, and at another it was 70 percent. While not reported as being present at every occurrence, bryophytes were often abundant, with up to 100 percent cover. Lichens were far less abundant, and liverworts were mentioned very infrequently. The amount of bare rock varied from 0 to 99 percent, and bare ground ranged from 0 to 40 percent. There may have been some inconsistency when evaluating cover. For example, litter is usually categorized separately from bare ground, but in one report a note specifically said that "bare ground" included litter. In addition, some life forms such as liverworts may go unrecognized, especially in a dense moss community.

A description of potential habitat for *Aquilegia brevistyla* has not been rigorously defined. Potential habitat can best be described as habitat that from casual observation appears suitable for the species, but is not occupied by it. The variability in *A. brevistyla* occurrence sizes may be significant, possibly indicating that there are considerable differences in habitat quality among the occurrences. Further study to relate the size and density of an *A. brevistyla* occurrence to the habitat characteristics may be very informative.

Reproductive biology and autecology

Aquilegia brevistyla is a perennial species that reproduces sexually (Munz 1946). The degree to which it reproduces vegetatively has not been reported and needs to be clarified, but it may be limited since the plant has only a short rhizome. It is unknown if a stand of several stems within a few square meters, often referred to as individuals by observers, may represent a single plant. This has important implications in assessing the conservation value of occurrences. For example, there might be 10 patches of plants, four of which have only three individual stems while six patches at another nearby site have 15 stems per patch. Eliminating the four smallest patches might suggest that less than 12 percent of the occurrence had been impacted. If each patch consisted of a single plant with multiple stems, however, 40 percent of the functional genetic population would have been removed, and thus the occurrence may have sustained a substantial loss of genetic diversity.

Aquilegia brevistyla flowers from late May to July. The flowers are hermaphroditic, having both male and female organs. The earliest date flowers have been documented in the Black Hills is May 22 (SD 39 in **Table 3**) and the latest is approximately July 28 (SD 38 in **Table 3**). Flowering time apparently depends upon environmental conditions. In Montana it was observed that if rains come after a dry spring and early summer, *A. brevistyla* flowers later than it does in years when there is adequate moisture early in the year (Roe 1992). Fruit starts to set in June and matures in July and August. Within an occurrence, individuals do not appear to be particularly synchronous. At any given time in June, some individuals may be vegetative while some may be in bud and others may have maturing fruits. The species can adapt to a short growing season; in southeastern Yukon plants that flowered on June 15 had mature fruit by July 23 (Porsild 1951).

Cytological studies of *Aquilegia* species are difficult because the chromosomes are small, the meiotic karyotypes of different species are similar, and the seven meiotic bivalents lack individuality (Taylor 1967). Chromosome number in *Aquilegia* taxa is typically diploid with 2n = 14. Occasional strains of *A. chrysantha* and *A. vulgaris* have been found to be aneuploid with 2n = 16 (Munz 1946, Fedorov 1969). This variability may also apply to *A. brevistyla*. Taylor (1967) found that 2n = 14 in all *A. brevistyla* specimens he examined, whereas Dawe and Murray (1981)

determined that a specimen of *A. brevistyla* collected in Alaska was an aneuploid with 2n = 16. *Aquilegia brevistyla* material was collected from the Little Belt Mountains in Montana in 1991 and sent to Trinity University, Texas, for genetic study that would likely have included chromosome counts (Montana Natural Heritage Program 2004). The results of this study are unavailable (Livingstone personal communication 2005, Young personal communication 2005), and the chromosome number of *A. brevistyla* needs to be reinvestigated (Whittemore 1997).

The reproductive biology and pollinators of *Aquilegia* species have been subjects of a number of studies, including Grant (1952, 1981), Brunet and Eckhart (1998), Fulton and Hodges (1999), and Hodges et al. (2002). None of these studies was specific to *A. brevistyla*. *Aquilegia* species may be self-pollinated or cross-pollinated (Brunet and Eckhart 1998). Some species of *Aquilegia* are protandrous, where the anthers mature before the carpels (Miller and Willard 1983). In protandrous, hermaphroditic species, the first flowers to open on a plant will tend to reach their female phase when later flowers are in the male phase, whereas the last flowers to open will reach the female phase when no other flowers on the plant are in male phase (Brunet and Eckert 1998). Therefore, pollinators are required even for self-pollination. Reproductive systems may be variable within an *Aquilegia* taxon. A study of *A. coerulea* showed it to be only partially protandrous, and in addition to between-flower self-pollination (geitonogamy), within-flower self-pollination (autogamy) was not uncommon within an occurrence (Brunet and Eckert 1998). A level of within-flower self-pollination (autogamy) is likely advantageous, since it can provide reproductive assurance, whereas between-flower self-pollination (geitonogamy) provides no such assurance (Eckert 2000).

Aquilegia brevistyla is at least partially cross-pollinated by insects, likely primarily bees (Nold 2003). Bumblebees (*Bombus* spp.) are reported to be the primary pollinators of *Aquilegia* species that have blue or purple flowers with short hooked spurs (Miller and Willard 1983). If this is so, spatially disjunct groups that are cross-pollinated are likely to have high levels of dispersal and gene flow between them. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m, with a range between 70 and 631 m, from the nest to forage even when apparently plentiful food was available nearby. Honeybees can regularly forage 2 km away from their hive (Ramsey et al. 1999).

The consequence of isolation and small population size in *Aquilegia brevistyla* has not been addressed, but by comparison to other *Aquilegia* species, the reproductive effort is unlikely to be compromised in isolated occurrences. Mavraganis and Eckert (2001) tested the hypothesis that reproductive output, which is an important part of population fitness, is positively associated with population size and isolation. Among Ontario occurrences of *A. canadensis*, large populations (n = >90 flowering plants) outcrossed twice as frequently as small populations (n = 30 to 40), in which inbreeding depression was apparent (Mavraganis and Eckert 2001). However, they found that even though inbreeding can significantly reduce the fitness of natural populations, there was no relationship between reproductive output and the isolated nature of populations. In fact they found that isolated populations had a slightly higher reproductive output for the level of inbreeding depression that they encountered (Mavraganis and Eckert 2001).

There is no information on the quantity or viability of seed produced by *Aquilegia brevistyla*. In many occurrences, the species has been observed to produce abundant fruit, but the number of seeds typically produced is unknown. Individual *A. chrysantha* plants in New Mexico produced fewer than 10 to more than 100 seeds, and production was closely related to environmental conditions (Strand 1997, Stubben and Milligan 2001). Plants tended to produce more seeds in years with relatively higher precipitation. The extent to which *A. brevistyla* seeds lie dormant in the seed bank is also not known. *Aquilegia chrysantha* and *A. pubescens* seeds experience dormancy (Strand 1997, Baskin and Baskin 2001). *Aquilegia pubescens* seeds experience a morphological dormancy (Baskin and Baskin 2001); the seed coat needs to be scarified before germination can occur.

Aquilegia brevistyla seed dispersal mechanisms are not known. Agents of seed dispersal may include water, wind, and animals. The small, black, smooth seeds of *A. brevistyla* have no obvious adaptations for specialized dispersal, such as barbs that would stick to animal fur or "wings" to facilitate wind-dispersal. The majority of seed may simply fall to the soil just below the parent plant. Water may contribute to *A. brevistyla* seed dispersal from plants growing at seeps or along streams and drainages. The contribution of water-induced soil erosion to seed dispersal at occurrences on steep slopes has not been documented. Wind is unlikely to be a significant seed-dispersal mechanism where occurrences are protected in deep canyons. In addition, wind-dispersed seeds often move only short distances

in other circumstances (Silvertown 1987). Animals can disperse seeds after ingesting and subsequently excreting them. Seed toxicity will influence what animals are involved in this seed-dispersal mechanism. Seed caching by rodents and other animals, including insects such as ants, may also contribute to dispersal, but there is no direct evidence to support this.

Demography

There have been no demographic studies of *Aquilegia brevistyla*. Population viability analyses have not addressed *A. brevistyla*, and a minimum viable population size cannot be estimated from the available data. In addition, there is no information as to the constancy of reproductive output and individual plant mortality or survival rates over time.

Aquilegia brevistyla seedlings have not been reported at any of the occurrences. This might be because seedlings are hidden in the abundant vegetation typical of *A. brevistyla* habitat, or it may be due to an actual rarity of seedlings. The preponderance of adults in populations may be ascribed to low seed production, high seed predation, low seedling survival and establishment, or a combination of all three. An additional or alternative explanation for the paucity of seedlings may be that seeds are stored in the seed bank and will only germinate when conditions are most favorable. Strand (1997) reported that seeds that had over-wintered at least once germinated from the seed bank. Stubben and Milligan (2001) estimated that the *A. chrysantha* seed bank might be depleted in five years if seed production ceased.

Stubben and Milligan (2001) studied the development of *Aquilegia chrysantha* in detail. A seed of *A. chrysantha* germinates and produces a rosette from which a flowering stalk develops. The rosette will have died by the following year, but another rosette develops on the caudex, usually under the old rosette (Stubben and Milligan 2001). Plants are thus iteroparous, reproducing for a number of years before they die. Older plants may have more than five rosettes, each producing a flowering stalk (Stubben and Milligan 2001). The caudex, or woody stem, serves as the organ of dormancy, and no rosettes are produced during a dormant year (Strand 1997). *Aquilegia chrysantha* plants can become dormant for at least one year during times of environmental stress. Species having organs that experience prolonged dormancy are not unusual among many geophytes (Lesica and Steele 1994).

A life cycle diagram for *Aquilegia brevistyla*, based on the results of Stubben and Milligan (2001) for *A. chrysantha*, is given in **Figure 6**. Species having a similar life form and regenerative strategy were characterized as being stress tolerant-competitors by Grime et al. (1988) and as *K*-selected species by MacArthur and Wilson (1967). *K*-selected species are defined as having a long life span in relatively stable habitats (MacArthur and Wilson 1967).

Field reports have frequently indicated that only vegetative *Aquilegia brevistyla* individuals were observed at an occurrence. Many *A. brevistyla* plants in an occurrence apparently do not flower in any given year, which indicates that annual seed production is not assured (**Table 3**). These observations suggest that adult plants are important for sustainable *A. brevistyla* occurrences. This deduction is consistent with the results from demographic studies conducted on *A. chrysantha*. Strand (1997) and Stubben and Milligan (2001) calculated the equilibrium growth rate and performed elasticity analysis for *A. chrysantha* occurrences from transition matrices across six years (five transition periods). Elasticities predict the proportional change in growth rate given a proportional change in a matrix element while all other elements remain constant (Mills et al. 1999). The highest elasticity was in the persistence of the medium-sized plants, which indicated that the adult plant and its rootstock are important stages in the life cycle of *A. chrysantha* (Strand 1997). Seed production and recruitment from the seed bank also had significant elasticity values over some transition periods, indicating that seed production and seedling recruitment might be critical in some years (Strand 1997). Strand's 1997 studies also indicated that both population size and individual fecundity and development were very sensitive to environmental conditions.

Studies of other *Aquilegia* species can be useful when considering the biology and ecology of *A. brevistyla*. The studies conducted on *A. chrysantha* by Strand (1997) and Stubben and Milligan (2001), combined with observations of *A. brevistyla* behavior, suggest that vulnerability to environmental conditions, especially drought, may contribute to temporally variable *A. brevistyla* occurrence sizes. In addition, the importance of mature adults and annual fecundity suggests that high soil disturbance and/or grazing during its reproductive period over several consecutive years may lead to unstable populations. However, while these data can provide valuable insights into the possible life history and ecological requirements of *A. brevistyla*,

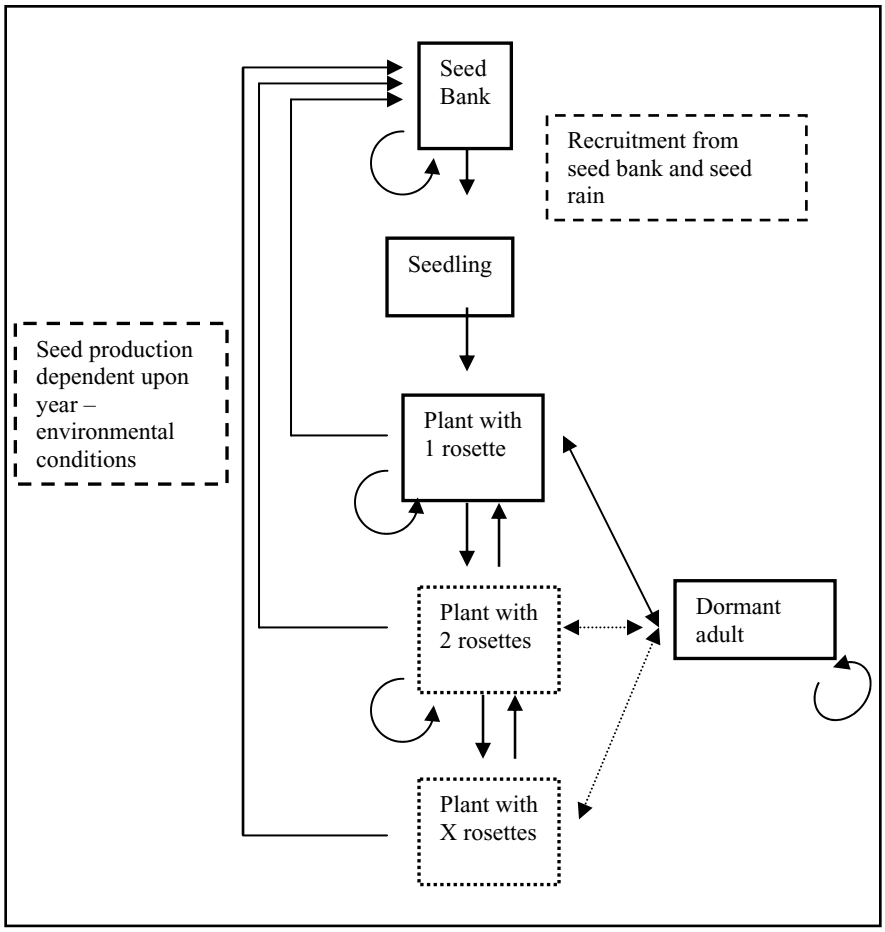

Figure 6. Life cycle diagram for *Aquilegia brevistyla* based on that for *A. chrysantha* var. *rydbergii* (after Strand 1997, Stubben and Milligan 2001).

they may also be misleading. These data were generated in studies of a different taxon in the Organ Mountains of New Mexico, which is a significantly different environment than the areas supporting *A. brevistyla*.

Hybridization between *Aquilegia* species is common (Taylor 1967, Whittemore 1997). Hybrids between *A. brevistyla* and *A. flavescens* have been found in the Lewis and Clark National Forest (Roe 1992). *Aquilegia canadensis* var. *hybrida* is not an accepted variety and is now considered a synonym of *A. canadensis* (Integrated Taxonomic Information System 2006). However, Munz (1946) suggested that some *A. canadensis* var. *hybrida* specimens might have resulted from hybridization between *A. canadensis* and *A. brevistyla*. The ranges of both taxa overlap in the Black Hills, and specimens of *A. canadensis* var. *hybrida* have been reported from South Dakota (Munz 1946). *Aquilegia canadensis* has been found in *Populus tremuloides/Corylus cornuta* (Aspen/Beaked Hazel), *Acer negundo/Prunus virginiana* (Box Elder/Chokecherry), and *Quercus macrocarpa/Ostrya virginiana* (Bur Oak/Ironwood) forests in the Black Hills (Marriott and Faber-Langendoen 2000a). These upland hardwood and riparian/wetland plant communities are not typical of the communities associated with *A. brevistyla*. However, several *A. brevistyla* occurrences have been found in mesic hardwood forests and riparian plant communities, so it is possible that both taxa can share habitats. The potential for sympatry and the frequency with which hybridization can occur in the Black Hills need to be explored. Pollinator preference, differences in flower structure, and/or spatial separation of species all contribute to genetic isolation of both the parents and their hybrid progeny (Grant 1981, Fulton and Hodges 1999). It may be that even though hybrids of *A. brevistyla* are produced, they will not naturally reproduce or introgress with parents.

Community ecology

Available information suggests that in the Black Hills National Forest, *Aquilegia brevistyla* is most often found in mesic coniferous forests, especially

Picea glauca forests. However, *A. brevistyla* is not very common within this habitat type. *Aquilegia* species were encountered infrequently during a community classification project conducted in the late 1990's (Marriott et al. 1999, Marriott and Faber-Langendoen 2000a, Marriott and Faber-Langendoen 2000b). *Aquilegia brevistyla* was not recorded in any of the associations, which included six stands of *Picea glauca/Linnaea borealis* and eight stands of *Picea glauca/Vaccinium scoparium* (Marriott and Faber-Langendoen 2000a). In contrast, *A. canadensis* was found in one out of nine stands of *Populus tremuloides/ Corylus cornuta*, one of three stands of *Acer negundo/ Prunus virginiana*, and one of 12 stands of *Quercus macrocarpa/Ostrya virginiana*, with a cover of one percent in each. *Aquilegia*, with no specific epithet, was found with a cover of one percent in one stand of *Populus angustifolia/Cornus sericea* woodland. The critical components of *A. brevistyla* habitat are not known. *Picea glauca* associations are late-seral types, and some ecologists consider them to be successional end points in the Black Hills (Hoffman and Alexander 1987, Marriott et al. 1999). Since *A. brevistyla* is strongly associated with late-seral communities, it is likely to take a long time to reappear when its associated community structure is altered by logging or other significant disturbance. While the likelihood that *A. brevistyla* is excluded from open sites is not definitive, it is clear that *A. brevistyla* generally occupies shaded or partially shaded locations. Shade may be provided by rock outcrops in canyons. This relationship is not unprecedented; many species of *Aquilegia* require shade or partial shade. The level of understory light was hypothesized to influence population size of yellow-flowered *Aquilegia* species in West Texas and New Mexico (Gallagher and Milligan 2001).

Microhabitat conditions may be very important to *Aquilegia brevistyla*. This species grows singly or in patches, but much apparently suitable habitat is unoccupied. Moisture, inter- or intra- species competition, light (canopy cover), and soil conditions are all likely to contribute to its patchy distribution within an occurrence. In a community classification study in Saskatchewan, *A. brevistyla* was the only taxon among more than 70 found in the riparian *Epilobium angustifolium* community that was found only in that community type (Korol 1996). This suggests that *A. brevistyla* may require a combination of microhabitat conditions that is not essential to other members of the community. This riparian habitat is similar to that initially understood to be required by *A. brevistyla* in the Black Hills (Kratz 2005).

Moss species are frequently reported as associates of *Aquilegia brevistyla* (**Table 1**, **Table 3**). *Hylocomium splendens* (feather moss) is a common associate in Montana. In the Black Hills, *A. brevistyla* frequently grows in carpets of moss. This association may provide *A. brevistyla* with a moister microhabitat soil environment in areas that superficially appear drier. Moss helps to maintain moist edaphic conditions because it can retain disproportionately large amounts of water. A square yard of dry moss, weighing 2.2 pounds, retains 11 pounds of water after a heavy rain (Dorst 1970). The exact water-holding capacity is likely to depend upon the moss species. The surface moss and lichen community may also be indicative of a specific soil microbiotic community that involves a myriad of biological interactions in the root zone. There is no information on mycorrhizal associations with *A. brevistyla*. Reports of an association between *A. canadensis* and vesicular-arbuscular mycorrhizae are contradictory (Sullivan 1992, Dawson and Ehleringer 1993). It is possible that environmental, principally edaphic, conditions affect the degree of association. Van Aarle et al. (2003) reported that arbuscular mycorrhizal root colonization of *Plantago lanceolata* was markedly higher in limestone soils (30 to 60 percent) than in acidic soils (5 to 20 percent), in both original habitat and in experimentally manipulated soils.

Aquilegia brevistyla is often found in areas with high vegetative cover and with a relatively high diversity of associated plant species. The *Epilobium angustifolium* community type in which it occurs in Saskatchewan had the second greatest species diversity and was the third richest (79 taxa) of the communities studied (Korol 1996), and several species of grasses and forbs had their peak abundance in this community. These levels of diversity and abundance are consistent over the range of *A. brevistyla*. Forbs are typically more abundant than grasses in Black Hills occurrences. One of the consequences of the high vegetative cover may be that *A. brevistyla* seedlings and vegetative plants are obscured during surveys. Under casual scrutiny, *A. brevistyla* leaves may also be mistaken for those of *Thalictrum* species, which are common within *A. brevistyla* habitat. Since *Thalictrum* species have inconspicuous flowers, misidentification can occur even when they are flowering.

Members of the Ranunculaceae are often poisonous, but there is no information about secondary plant compounds in *Aquilegia brevistyla*. The Miwok Native Americans boiled and ate the young leaves of *A. formosa* in the spring, suggesting that palatability of

vegetation may vary during the growing season. The palatability of *A. brevistyla* to wildlife, such as deer and elk, has not been reported. *Aquilegia brevistyla* may be in too low abundance to be significant in wildlife diets. For example, *Aquilegia* species were not mentioned as a component of deer habitat in the Black Hills of South Dakota (Thilenius 1972). Although the roots and leaves of several *Aquilegia* species contain pharmacologically active compounds, the seeds usually have the highest levels of such compounds (Moerman 1998). The seeds of some species are particularly toxic (Tampion 1977, Woodward 1985). Most studies relate to human toxicity, but the results of one analysis indicated that extracts of *A. vulgaris* had pharmacological activity in rodents (Adamska et al. 2003). It was not clear if the activity at levels found in nature is significant. Caching and dispersal of *A. brevistyla* seeds by rodents and other animals are unlikely if they are toxic. While determination of the compounds in *A. brevistyla* seeds would allow inference of typical interactions, species-specific studies are needed due to the variability of animal sensitivity to these compounds. *Aquilegia* species may be the sole source of food for the larvae of *Erynnis lucilius*, the Columbine Dusky Wing butterfly (Scott 1986, 1997). In northern Manitoba, *A. brevistyla* is likely to serve as the host plant for this butterfly species (Klassen et al. 1989).

Aquilegia species are typically cross-pollinated (Miller and Willard 1983). The flower color and the length, shape, and orientation of the nectar spurs all influence the types of pollinator species (Hodges 1997). Red-flowered *Aquilegia* species are primarily pollinated by hummingbirds, pale-colored and yellow-flowered *Aquilegia* species by hawk- and sphinx moths, and blue-flowered *Aquilegia* species, such as *A. brevistyla*, by bumblebees (Clausen 1951, Grant 1952, Grant 1981, Miller and Willard 1983, Miller 1985). This specialization among pollinators may contribute to the genetic isolation of sympatric species (Grant 1952, Hodges 1997). However, in Colorado, hummingbirds, sphinx moths, and several species of bumblebees were observed visiting *A. coerulea*, but not all within the same occurrences (Grant 1976, Miller 1978). Chase and Raven (1975) noted that bumblebees, hawk moths, and hummingbirds all visited red-flowered *A. formosa*, which is a member of the *A. canadensis* complex. They concluded that adaptation to different habitats and spatial separation were likely to be the most important factors in maintaining genetic isolation between two *Aquilegia* species in California. Different structural characteristics of the flower, such as the floral tube length, can also prevent pollen transfer between species (Grant 1981). Although potential pollinator-visitors are the same for all species in a given area, differences in flower structure prevent effective pollen transfer. The observation that hybridization occurs between *A. flavescens* and *A. brevistyla* in the Lewis and Clark National Forest indicates that they share pollinators, most likely bumblebees (*Bombus* spp.).

The ability to self-pollinate may be important in small populations of a species that is primarily pollinated by bees because bees, unlike some flower visitors such as hawk moths, are density-dependent foragers (Heinrich 1976). Small populations of *Aquilegia brevistyla* with few flowers may be pollinator-limited. In addition, the size of the *A. brevistyla* patch may influence the frequency with which cross-pollination occurs. Bumblebees were observed to preferentially visit large clumps of *Astragalus canadensis* in an Iowa prairie (Platt et al. 1974). Although the patch size of *Aquilegia brevistyla* may be mitigated by the abundance of other flowering vegetation, the increased availability of alternative flowering species may negatively influence the likelihood of sequential visits to *A. brevistyla* flowers in a sparsely occupied occurrence.

An envirogram is a graphic representation of the components that influence the condition of a species and, ideally, reflects its chance of reproduction and survival. Envirograms have been used primarily to describe the condition of animals (Andrewartha and Birch 1984), but they may also be applied to describe the condition of plant species. Those components that directly impact *Aquilegia brevistyla* make up the centrum, and the indirectly acting components make up the web (**Figure 7**, **Figure 8**). Much of the information to make a comprehensive envirogram for *A. brevistyla* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the resources that are likely to impact the species directly. Dotted boxes indicate the resources, such as shade, that are more speculative. There is a lack of direct studies on this species that leads to the stretching of the significance of observations and forming hypotheses from inference rather than direct observations. Inferences must be tested and have limited value in predicting responses to management decisions.

The resources of *Aquilegia brevistyla* include a suitably damp environment maintained either by precipitation and environmental conditions or by hydrological features, such as seeps, springs, and streams. Shade is included in the envirogram in a dotted box because the extent of optimal canopy closure is not known and the contribution of geological features in providing appropriate light conditions is

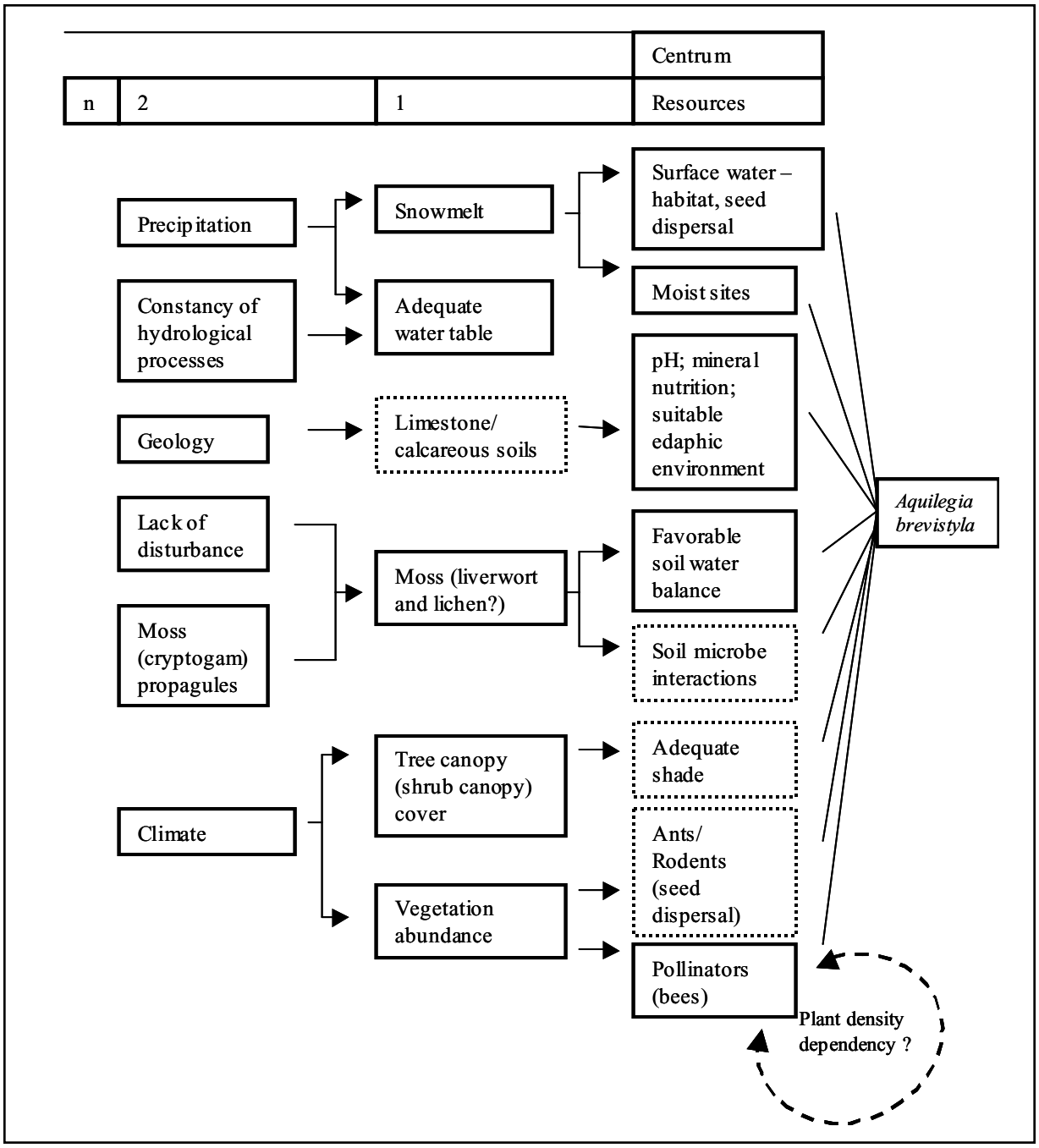

Figure 7. Envirogram outlining the resources to *Aquilegia brevistyla*. Solid boxes indicate resources having more evidence than those in the dotted boxes.

not known. Pollinators are likely to be important for cross-pollination. The line with the double-arrow in the diagram indicates that there may be an interaction between flower density and pollinator success. Water, rodents, arthropods, and wind may be agents of seed dispersal. Climatic factors such as temperature and precipitation are likely to influence the abundance of both *A. brevistyla* plants and their pollinators.

CONSERVATION

Threats

The most likely immediate and potential threat to *Aquilegia brevistyla* on Region 2 and Region 1 NFS land is habitat loss. Recreational activities in some areas of Regions 1 and 2 currently threaten some occurrences

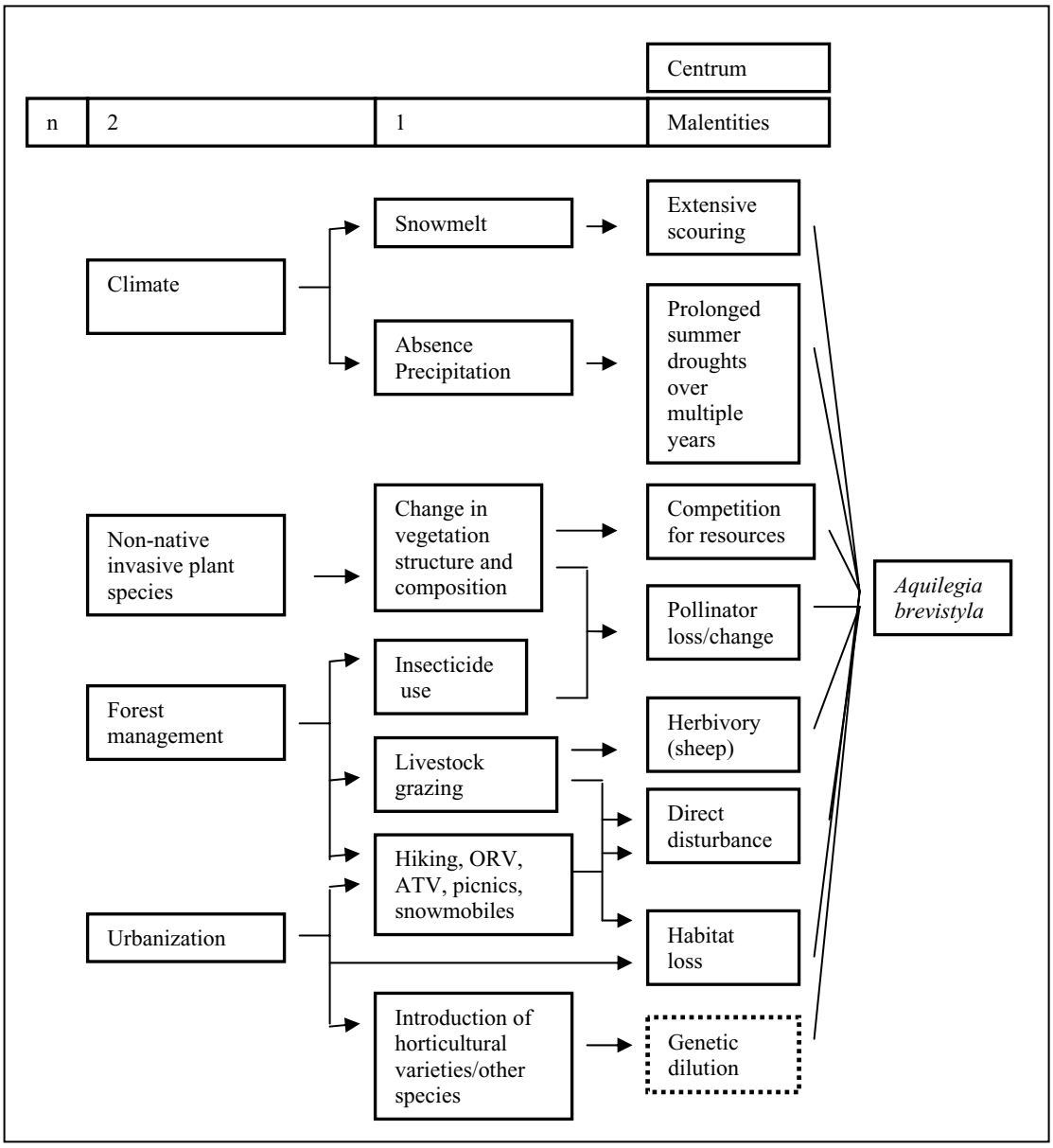

Figure 8. Envirogram outlining the threats and malentities to *Aquilegia brevistyla*. Potential interactions between factors, for example vehicles contributing to weed seed dispersal, are not illustrated. A solid box indicates a threat or malentity with more supporting evidence than those in a dotted box.

and habitat. Potential anthropogenic sources of habitat loss include livestock grazing, extraction of natural resources (e.g. minerals, oil, natural gas, and timber), fire and/or fire-suppression, invasion of exotic plant species, and urbanization and rural residential development. Modification of hydrologic conditions poses a potential threat in some areas. Over-collection of flowers or plants is a potential threat, but at the current level of activity over-collection would only affect small occurrences and is not perceived to be a significant threat. Disturbance from the anthropogenic sources above and from natural processes may have direct, indirect, and synergistic consequences. *Aquilegia brevistyla* plants may be directly damaged or killed by the agent of disturbance or the habitat may become modified, which may affect occurrence sustainability. Increased soil erosion from any source of disturbance may increase sediment deposition in streams, which could have unpredictable consequences on streamside occurrences of *A. brevistyla*. Small increases in deposition over a long period may not have a substantial impact on plants growing on stream banks; their root systems may actually benefit from fractionally more soil accumulation. However, copious

sediment deposition may bury seeds and roots so deeply that they are unable to sprout. Another consequence of increased sediment deposition that needs further study is the potential alteration of the nutrient dynamics of the system. Although some *A. brevistyla* plants have been found near trails and road cuts, there is no indication that disturbance is a significant factor in *A. brevistyla*'s life cycle. The current plants at such sites may even be remnants of occurrences that were there prior to the disturbance.

A potential threat to the long-term reproductive success of *Aquilegia brevistyla* occurrences may be changes in pollinator assemblage or declines in pollinator abundance. Environmental, demographic, and genetic stochasticities present potential threats to all plants, but small, disjunct *A. brevistyla* occurrences in the contiguous United States may be particularly vulnerable.

Recreation

Recreation activities may pose a threat to some *Aquilegia brevistyla* occurrences in Montana and the Black Hills. *Aquilegia brevistyla* was discovered in 1967 along the Boulder River in Montana, an area heavily used for recreation and fire-wood cutting; it has not been relocated since the original collection (Mathews 1989, Montana Natural Heritage Program 2004). Some areas on the Black Hills National Forest in which *A. brevistyla* occurs are readily accessible to the public and are developed recreation areas (e.g., campsites near SD 6, 7, 19, 23, 40, 44, 46, and 51 in **Table 3**). Trails appear to have bisected existing occurrences. For example, it is likely that *A. brevistyla* plants on each side of the Beaver Creek ski trail system (SD 19 in **Table 3**) and plants between the trail and the creek at Montana occurrence 10 (**Table 1**) may have been there prior to trail establishment.

Recreational off-road vehicle traffic and all-terrrain vehicles (ATVs) have gained popularity in North America within the last decade (ATV Source 1999-2004, OffRoadDirectory.net 2004). Motorized recreation is a popular pastime on the Black Hills National Forest (Paterson 2004, USDA Forest Service 2004a). Recent ATV tracks have been reported from Black Fox Bog (affecting SD 22 and 23 in **Table 3**) and Elk Creek (directly affecting SD 56 in **Table 3**). The damage caused within only one day (10-Jun-2005) by twelve 4-wheeler ATVs and one dirt bike in and around Black Fox Bog was documented with photographs (see Norbeck Society 2005). Snowmobiles are used in many regions in winter, and the Black Hills National Forest is a popular snowmobiling area (Wyoming Snowmobile Association. 2004). Impacts of motorized vehicles specifically on *Aquilegia brevistyla* habitat have not been studied in detail. Studies of motorized vehicle impacts have been made in various habitats, and the evidence indicates that all forms of motorized recreation can severely disturb vegetation, cause accelerated soil erosion, increase soil compaction, and add to pollution (Keddy et al. 1979, Aasheim 1980, Fahey and Wardle 1998, Forbes 1998, Belnap 2002, Misak et al. 2002, Gelbard and Harrison 2003, Durbin et al. 2004). Although impacts are probably cumulative and in proportion to the number of vehicles, a single pass of one snowmobile causes significant snow compaction, which adversely affects snow permeability, soil properties beneath the snow, and snow melt properties (Keddy et al. 1979, Fahey and Wardle 1998). Occurrences of *A. brevistyla* on lower slopes and in the creek bottoms are particularly vulnerable to motorized vehicles. In addition, vehicles on moderate inclines or trails up-slope may also impact occurrences on less accessible terrain below them through increased erosion and the initiation of avalanches or landslides.

Livestock and wildlife

Commercial livestock grazing is common throughout the range of *Aquilegia brevistyla*. *Aquilegia* species are generally sensitive to overgrazing and "due to past mismanagement, columbines have been greatly reduced on sheep ranges in Colorado where formerly they were plentiful" (USDA Forest Service 1988). Sheep grazing on the Black Hills National Forest was highest in the late 1800's, but it was prohibited completely in 1909 when it was obvious that serious degradation to the environment had occurred (USDA Forest Service 1997). Sheep grazing was allowed again in 1916 and has been permitted sporadically in the Black Hills since that time (USDA Forest Service 1997). There are no sheep grazing allotments at the current time in the Black Hills National Forest (USDA Forest Service 1997, field survey forms from the Black Hills National Forest courtesy Cynthia Buckert and Beth Burkhart, Black Hills National Forest 2004). The majority of the *A. brevistyla* occurrences on the Black Hills National Forest are within cattle grazing allotments (**Table 3**). Livestock typically use drainage bottoms and lower slopes, and therefore are not expected to directly disturb plants on steep slopes and sheer-rock walls. Specific information on the palatability of *A. brevistyla* is unavailable. Some *Aquilegia* species are rated fair for sheep, poor for cattle, and "practically worthless for horses" (USDA Forest Service 1988). The extent to which *A. brevistyla* is grazed probably depends on the amount of available

alternative forage. Use may also depend upon the time of year. Young shoots are generally more palatable than older vegetative parts of many plant species (see Community Ecology section). The impacts of wildlife browsing on *A. brevistyla* have not been documented. Direct trampling by large herbivores such as elk (*Cervus elaphus*) is likely to disturb plants, especially in areas where animals congregate.

Resource extraction

Development of oil and gas resources is unlikely to impact occurrences on the Black Hills National Forest. Most of the extraction activity occurs in Custer County, where there are some wells on private land within the boundaries of the Black Hills National Forest (USDA Forest Service 1997). As of 1997, there were no producing wells on lands managed by the Black Hills National Forest, and little activity was expected in the foreseeable future (USDA Forest Service 1997). Oil and gas exploration and development could impact some occurrences on the Lewis and Clark National Forest in Montana. There is substantial oil and gas potential in the Overthrust Belt, which runs along the Rocky Mountains from New Mexico to Montana, and one of the best prospective sources of natural gas is beneath the Lewis and Clark National Forest (Kenworthy 2001). Forty-two percent of the land managed by the Lewis and Clark National Forest is open to oil and gas leases; the rest (approximately one million acres) was closed to oil and gas development in 1997 until at least 2006 (USDA Forest Service Lewis and Clark National Forest 1997).

The Black Hills are rich in mineral resources (USDA Forest Service 1997). Limestone, an important commodity used in a variety of industries from cement production to sugar beet processing, is quarried in the Black Hills of South Dakota (U.S. Geological Survey/ South Dakota Geological Survey 2003, Wyoming State Geological Survey 2005). The Black Hills are famous for their gold mining operations, located principally in the northern Proterozoic formation of sedimentary rocks (Caddey et al. 1991, Partington and Williams 2000, Wharf Resources (USA) Inc. 2005). Gold mining is currently at much lower levels than in the past, and its importance to the economy may be reduced further in the future (U.S. Geological Survey/South Dakota Geological Survey 2003). For example, the extensive gold mining operation at Bald Mountain (in the vicinity of SD 55 in **Table 3**) is currently drawing to a close (Wharf Resources (USA) Inc. 2005). Pegmatite minerals, found in the Central Crystalline Core of metamorphic rocks, have been mined since the 1870's and remain important to the economy (USDA Forest Service 1997). However, many of the various mines that began operations in the nineteenth century ceased operations in the 1920's, having exhausted the most readily accessible deposits (DeWitt et al. 1986). Mining has also contributed to water contamination in the area (Carter et al. 2002). The extent to which the various mining and quarrying operations in the Black Hills have modified *Aquilegia brevistyla* habitat or impacted occurrences is not specifically documented.

Logging and mechanical forest thinning occurs within *Aquilegia brevistyla* habitat. Both activities contribute to soil disturbance and reduce the overstory canopy. The extent to which the overstory is necessary to sustain *A. brevistyla* occurrences has not been critically evaluated. *Aquilegia brevistyla* is commonly reported in partial shade to shaded conditions whereas it is reported only rarely from open sites. *Aquilegia brevistyla* occurrences are likely to be less affected by a loss of forest canopy in deep canyons that experience shade from cliffs and slopes. Threats from timber sales on the Black Hills National Forest are perceived to be low at the current time (Buckert personal communication 2005, Burkhart personal communication 2005). In particular, many of the *A. brevistyla* occurrences in *Picea glauca* forests are in low priority target areas for logging (Burkhart personal communication 2005).

Fire and fire suppression

The role of fire disturbance in the ecology of *Aquilegia brevistyla* and the fire regime in which it evolved are not well known. Historically, fires were infrequent in mesic *Picea glauca* forest ecosystems (Marriott et al. 1999). However, fire-scar evidence indicates that relatively frequent surface fires occurred in most of the *Pinus ponderosa* forest across the Black Hills (Brown 2003). Surface fire frequency reconstructed from fire scars varied from 30 to 33 years *in P. ponderosa* stands at higher elevations. In addition, early records from the Black Hills indicate extensive areas of crown mortality from pre-settlement fires (Graves 1899, Dodge 1965, Shepperd and Battaglia 2002). Fires largely ceased after Euro-American settlement in the late 1800's (Brown 2003). The response of any taxon to fire is likely to depend on the intensity, frequency, extent, and season of the fire (Whelan 1997). The moist habitats of *A. brevistyla* are likely to experience infrequent high intensity fires and may provide refugia from low intensity fires. After a 1991 fire in the Lewis and Clark National Forest, *A. brevistyla* plants were found only in the duff that had not burned (Roe 1992). Several *Aquilegia* species are

reported to be fire-adapted (Gough 2005). *Aquilegia brevistyla* may be best categorized as a "fire evader," having both rhizomes and seeds stored in the soil (Lyon and Stickney 1994, Whelan 1997). However, its moist-soil habitat may mean that its underground stems are more susceptible to damage by fire than if it grew in dry sites. Although soil is typically a good insulator, moist soil often reaches a higher peak temperature and reaches it more rapidly than does air-dry soil at the same depth (Whelan 1997). In isolated occurrences, it may be that the seed bank rather than seed rain is important for recovery after fire.

The consequences of fire suppression are equally difficult to evaluate. In the Black Hills, *Aquilegia brevistyla* is most commonly found under *Picea glauca*, but it is also found in mixed stands of *Pinus ponderosa* and hardwood. A study of the fire regime from 1580 to 1890 focused on the Black Elk Wilderness Area in the Upper Pine Creek Basin (Brown et al. 2000). This is an area in the Black Hills that is dominated by forests of *P. ponderosa* mixed with *Picea glauca* and *Populus tremuloides* and has received little anthropogenic disturbance (Ryan et al. 1994, Brown et al. 2000). The last fire recorded in this basin was in 1890 (Brown et al. 2000). Because the median fire interval in this area prior to 1890 was 22 to 23 years, fire would appear to be a regular feature in the life history of established *A. brevistyla* occurrences, and fire suppression might be assumed to be detrimental. However, the fire return interval at any particular site ranged from 11 to 74 years due to local differences in forest conditions. It is unknown how *A. brevistyla* habitat relates to these local conditions. If *A. brevistyla* naturally grows in areas with long fire-return intervals, then fire suppression in the recent past may have had little effect and may even have had a favorable impact. Alternatively, if *A. brevistyla* is a fire-adapted species that naturally grows in areas with relatively short fire-return intervals, fire suppression may have contributed to loss of habitat.

Urbanization and rural residential development

Development at and beyond the urban fringe is following two routes in the Black Hills: incremental expansion of urban areas, and scattered residential development. Urbanization and residential development lead to habitat degradation and fragmentation. The impacts of residential development extend beyond direct disturbance caused by building houses and a supporting infrastructure, and include indirect consequences such as modification of water availability and fire regimes. The human populations of three counties (Pennington, Custer, and Lawrence) largely within the Black Hills of South Dakota have on average increased more than 10 percent between 1990 and 2000 (U.S. Census Bureau 2005). The Black Hills National Forest ranks eleventh in the United States in having the most private land within its boundaries. Many ranches within the Black Hills National Forest have been converted to housing developments within the last few decades (See Appendix F in USDA Forest Service 1997), and the urban-wildland interface has increased accordingly. An additional consideration of human population size is that, although there are approximately only 125,000 people living year-round in the Black Hills, the area receives about 4 million tourists annually. Higher levels of tourism are likely to increase pressure on water supplies, especially during periods of drought.

The mix of wildlands and housing developments tends to promote fire suppression and is also likely to encourage increased forest thinning to prevent wildfire in the future. A current example is the project proposed near Rochford (Atkins 2004) that is also the site of the 1897 *Aquilegia brevistyla* occurrence (SD 26 in **Table 3**). Mechanical forest thinning contributes to soil disturbance and reduces the overstory canopy, which may lead to a reduction in potential habitat for *A. brevistyla*. It is not clear as to how much these forest health management activities will impact *A. brevistyla* occurrences.

Water availability (Hydrology)

In South Dakota, Wyoming, and Montana, the majority of *Aquilegia brevistyla* occurrences are found in mesic areas that are vulnerable to water development projects as well as lengthy droughts. Water diversions for mining and hydroelectric power have had major impacts on streams in some parts of the Black Hills (Marriott et al. 1999). Stream dynamics and riparian vegetation have also been altered due to shrinking beaver populations (Parrish et al. 1996, Marriott and Faber-Langendoen 2000b). Even though *A. brevistyla* plants have been found outside of riparian and wetland meadow areas in the Black Hills, their associated communities typically require moist soils (Mariott et al. 1999, Marriott and Faber-Langendoen 2000a, Marriott and Faber-Langendoen 2000b). The Black Hills are an important recharge area for aquifers in the northern Great Plains, and water originating from the Black Hills is used for municipal, industrial, agricultural, and recreational purposes throughout much of western South Dakota (Carter et al. 2002). Although water quality may become an issue, in the foreseeable future the total volume of available water is not seen as limited given projected requirements and stored water

(Carter et al. 2002). Carter et al. (2002) noted that water measurements were made for their study in the middle to late 1990's. These years stand out as the wettest period in the region since 1931, and this resulted in data biased toward an overestimate of available water. This potential bias was addressed in their analysis of hydrologic data throughout the course of their study, and it was balanced to some extent by relatively dry conditions during the late 1980's and early 1990's (Carter et al. 2002). Water use is likely to increase in the future as human populations increase.

Invasive non-native plant species

Vehicles, livestock, and hikers all contribute to the spread of non-native plant species, because the soil disturbance generated by their actions creates favorable conditions for non-native plant establishment (Sheley and Petroff 1999). Contrary to some hypotheses that consider areas with high species diversity and high foliar cover less prone to invasion, Stohlgren et al. (1999) reported that sites high in herbaceous foliar cover and "hot spots" of plant diversity are susceptible to invasion in many landscapes. Therefore, *Aquilegia brevistyla* habitat may be vulnerable to invasion by non-native plant species. Because *A. brevistyla* evolved in a well-vegetated environment, it may be relatively competitive with respect to resource acquisition, but its vulnerability will likely depend upon the invading species. *Aquilegia brevistyla* is not highly rhizomatous, and its natural low frequency within an occurrence suggests that it does not proliferate rapidly. In addition, some noxious weed species secrete allelopathic chemicals into the soil that can also contribute to habitat loss (Sheley and Petroff 1999, Inderjit 2005). Houndstongue has been observed at occurrences SD 19 and WY 5 (**Table 3**) in the Black Hills. This species is listed as a noxious weed in South Dakota, Wyoming, and adjacent states (South Dakota Department of Agriculture 2004, Wyoming Weed and Pest Council Undated). Another noxious weed, Canada thistle, was found at occurrence SD 32 (**Table 3**). There are many occasions when herbicide application is both appropriate and necessary for forest management (Society of American Foresters 2001). However, there is the potential that broadleaf-selective and non-selective herbicides used to control non-native invasive species may affect *Aquilegia* species as well as the target plants (Marrs et al. 1989). The potential for negative effects depends upon the chemical and its application rate, timing, and mode of application. The negative effects from herbicide drift on non-target species are well documented in the agronomic and weed science literature (e.g., Hall et al. 1983, Fletcher et al. 1996, Obrigawitch et al. 1998, Boutin and Rodgers 2000, Boutin et al. 2000). From a purely ecological perspective, the influence of herbicides on native forbs in the field seems to have rarely been evaluated (Fuhlendorf et al. 2002). One study in Great Plains grasslands suggested that one effect of broadleaf herbicides might be to decrease rare forb species (Fuhlendorf et al. 2002). This observation may be supported by another field study that was designed to assess the effects of herbicide drift on the botanical diversity of arable field boundary vegetation (Kleijn and Snoeijing 1997). A decrease in biomass production of spontaneously colonizing forbs and increased species extinction rates in individual years were noted at low levels of herbicide exposure (Kleijn and Snoeijing 1997).

Collection

A potential threat that is linked to the recreational use of occupied *Aquilegia brevistyla* habitat is casual flower picking; *A. brevistyla* flowers are conspicuous and attractive (Fertig 2001). The potential impact of flower picking on seed set and long-term abundance in the recreational areas where *A. brevistyla* occurs has not been evaluated. Given its perennial nature, only over-collection from small occurrences in consecutive years is likely to significantly impact long-term population viability. No threats from commercial *A. brevistyla* collection have been documented, and the commercial availability of *A. brevistyla* appears to be limited. *Aquilegia brevistyla* is available in the horticultural trade, but there are no published figures to document its popularity (Chittenden 1974, Bailey et al. 1976, Prairie Habitats 1999). *Aquilegia brevistyla* is sold by a commercial nursery in British Columbia (Native Plant Society of British Columbia 2002).

Changes in pollinator assemblage and/or abundance

Long-term reproductive success of *Aquilegia brevistyla* may be vulnerable to declines in pollinator populations or changes in species assemblages because a degree of cross-pollination is likely to be important for adequate seed set and maintenance of genetic flow between individuals and occurrences (see Reproductive Biology and Autecology and Demography sections). Bees are understood to be the primary pollinators of *A. brevistyla*, but some evidence suggests that hawk or sphinx moths are also potential pollinators. Pesticide applications to control arthropod pests related to agricultural or forestry concerns may negatively affect pollinator assemblages and abundance in the vicinity. For example, the mountain pine beetle (*Dendroctonus*

ponderosae) is in epidemic proportions in parts of the Black Hills National Forest (USDA Forest Service 2003c, 2004b). Carbaryl (Sevin), is commonly used against several *Dendroctonus* beetle species but is highly toxic to bees (Cranshaw 1998). Several other pesticides impact bees as well as the target pest species (Kevan 1975, Larmer 1997). Even if pesticides are not used on National Forest System land and are only used on adjacent private lands, they may still impact pollinator populations, which do not respect administrative boundaries. Pesticides considered safe for humans, such as *Bacillus thuringiensis* (Bt), might influence pollinator assemblages where the urban community is growing within the Black Hills. Bt often specifically targets Lepidopteran pests (Cranshaw 1998). Since hornworms, the larval stage of hawk moths, are Lepidopterans, they are also particularly susceptible to Bt (Cranshaw 1998). Habitat alteration and fragmentation and the introduction of non-native plants and animals all contribute to reducing pollinator population sizes and can cause the extirpation or extinction of individual pollinator species (Bond 1995, Kearns et al. 1998). For example, sheep grazing may be detrimental because it can destroy wild bee nests (Sugden 1985).

Environmental stochasticity

Like all plants, *Aquilegia brevistyla* occurrences are vulnerable to environmental stochasticity and natural catastrophes. Environmental stochasticity includes random unpredictable changes in weather patterns or in the biotic members of the community; examples of natural catastrophes include wildfire and landslides (Frankel et al. 1995). Specific environmental factors that may affect *A. brevistyla* include variations in temperature, precipitation, soil erosion, and changes in the abundance and species of wildlife, particularly arthropods. Environmental stochasticity includes elements of global climate change, which if associated with drier and warmer conditions, may adversely affect *A. brevistyla*. Warming could cause tree lines to rise by roughly 107 m for every degree Fahrenheit of warming. Mountain ecosystems could thus shift upslope, reducing habitat for many species (U.S. Environmental Protection Agency 1997). Species that need moist conditions may be particularly vulnerable to a warmer, drier climate. Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), temperatures in Wyoming could increase by an average 4 ºF (2 to 7 ºF) in spring and fall, 5 ºF (2 to 8 ºF) in summer, and 6 ºF (3 to 11 ºF) in winter by 2100 (U.S. Environmental Protection Agency 1998a). Based on the same HadCM2 model, by 2100 temperatures in Montana could increase by about 4 ºF (1 to 8 ºF) in spring and summer and 5 ºF (2 to 10 ºF) in fall and winter (U.S. Environmental Protection Agency 1997). In the same time period in South Dakota, temperatures could increase by 3 ºF (1 to 6 ºF) in spring and summer and 4 ºF (2 to 7 ºF) in fall and winter (U.S. Environmental Protection Agency 1998b). A drying trend is predicted in Wyoming, but a moderate increase in precipitation is predicted for South Dakota (U.S. Environmental Protection Agency 1998a, U.S. Environmental Protection Agency 1998b). Although over the last century precipitation has decreased by up to 20 percent in southeastern Montana, there may be a slight increase in total precipitation in the future (U.S. Environmental Protection Agency 1997). Because spruce trees grow at higher elevations in the Black Hills and predominantly on northern slopes, soil moisture in those systems is heavily dependent on snowfall (Shepperd and Battaglia 2002). Some climate change models, such as HadCM2, have suggested that future snowfall may be higher than the historic average (U.S. Environmental Protection Agency 1997). This may mitigate the summer heat-induced drought scenario, but a warmer climate may lead to earlier and more intense spring snowmelt. High instream flows in spring may contribute to extensive scouring and local extirpation of creekside patches of *A. brevistyla*. These are only a few of the possible climate change scenarios. More information on the consequences of climate change can be found in Christy (2000), Alley (2002), Pew Center (2005), New Zealand Climate Change Office (2006), and U.S. Global Change Research Program (2006).

The majority opinion is that global climate change will cause the weather to become more extreme in the Black Hills region; winter storms will become more severe, and there will be more extremely hot days in the summer. Many *Aquilegia* species are sensitive to environmental conditions (Strand 1997). However, the observation that the flowering time of *A. brevistyla* is sensitive to environmental conditions suggests that rather than a liability, this plasticity might be an advantage in adapting to an unstable global environment. Much more information is needed before any accurate predictions can be made as to the species' response to environmental changes.

Demographic and genetic stochasticities

Demographic and genetic stochasticities are elements that affect the sustainability of plant populations. These are typically included in population viability analyses (Shaffer 1981, Menges 1991).

Demographic stochasticity refers to chance events independent of the environment that may affect the reproductive success and survival of individuals (Kendall and Fox 2002, 2003). Demographic stochasticity may be significant where there are only a few individuals in a population (Pollard 1966, Keiding 1975). Many *Aquilegia brevistyla* occurrences are small, so the fate of an individual plant can be relatively important in these occurrences.

Genetic stochasticity refers to intrinsic factors that influence the genetic composition of a population. Small, isolated populations of plants can be genetically depauperate as a result of changes in gene frequencies due to inbreeding, founder effects, or bottlenecks (Barrett and Kohn 1991, Menges 1991). A reduction in genetic diversity may mean that plants have a lessened ability to adapt to changing environmental conditions or introduced pathogens. Some studies suggest that certain *Aquilegia* species may experience some level of inbreeding depression due to selfing (Montalvo 1994, Brunet and Eckert 1998, Griffin et al. 2000, Mavraganis and Eckert 2001). The possibility that small populations of *A. brevistyla* in fragmented habitat experience inbreeding depression has not been explored (see Reproductive Biology and Autecology section). The small size of *A. brevistyla* occurrences may be a concern because from a genetic perspective, natural populations often behave as if they were even smaller than a count of individuals indicates (Barrett and Kohn 1991). It is not clear whether the patchy pattern typical of *A. brevistyla* plants is solely related to limited seed dispersal. If seed dispersal is limited, pollen transfer between occurrences may be critical to maintain gene flow and diversity.

Inbreeding is not always detrimental in small populations. It can purge deleterious recessive mutations, thereby avoiding inbreeding depression (Byers and Waller 1999). However, evidence suggests that purging depends upon a range of factors and that it is an inconsistent force within populations (Byers and Waller 1999). Studies have indicated that life history traits influence the extent of purging; perennials were less likely to exhibit purging than annuals (Byers and Waller 1999).

The potential that *Aquilegia brevistyla* might be threatened by outbreeding depression has not been evaluated. Outbreeding depression can result when local adaptations are disrupted by the introduction of non-local genotypes (Waser and Price 1989, Lesica and Allendorf 1999, Hufford and Mazer 2003). If *A. brevistyla* were to be used in commercial or restoration seed mixes, outbreeding depression might be a concern. *Aquilegia brevistyla* was recommended for use in restoration projects in Alberta (Banff National Park 2004) and Saskatchewan (Kosowan and Smith 2004). General recommendations were made for sources of material in Alberta, but there were no suggestions as to the seed source for the Saskatchewan project. Movement of *A. brevistyla* genotypes (ecotypes) outside their natural range in Region 2 appears to be remote at the present time since the taxon is not currently included in revegetation seed mixes. The increasing number of private homes with gardens in the Black Hills may increase the likelihood of horticultural varieties of *A. brevistyla* or other *Aquilegia* taxa "escaping" into the forest. A significant loss of genetic integrity through hybridization with naturally sympatric species of *Aquilegia* seems unlikely, because most reports suggest that naturally occurring hybrids are reproductively isolated from the parent taxa (see Reproductive Biology and Autecology section). However, the potential for hybridization between *A. canadensis* and *A. brevistyla* and the establishment of their hybrids cannot be discounted without further study.

Threats rangewide

Aquilegia brevistyla is also subject to threats and habitat loss in parts of its range outside the contiguous United States. In Alaska and parts of Canada, this species occurs in remote areas that nonetheless have been impacted by human recreation, utility corridors, and resource extractive industries such as oil, gas, minerals, and timber. For example, in 1949, *A. brevistyla* was collected from Birch Lake in Alaska, which has since been developed as a recreation area (Alaska Department of Fish and Game Undated). Comparing directions in Bell's Travel Guides (2003) to the original label on the 1988 herbarium specimen, a parking lot appears to be at the site of an Alaskan occurrence. It is not known if the collection was made before the parking lot was built. Occurrences have been found at Telegraph Creek in British Columbia. The creek was named for an overland telegraph line to the Yukon, but the positions of occurrences with respect to the telegraph right-of-way are unknown. In both Alaska and Canada, oil and gas development is widespread throughout *A. brevistyla* habitat, but impacts specifically to *A. brevistyla* populations have not been evaluated. Global climate change resulting in warmer temperatures may eventually impact northern occurrences. Isolated occurrences throughout the range of *A. brevistyla* are also likely vulnerable to demographic and genetic stochasticities.

Summary

In summary, the distribution of *Aquilegia brevistyla* suggests that the taxon is unlikely to be vulnerable to extinction throughout its entire geographic range. Some occurrences may be vulnerable to local threats and extirpation. Threats and malentities of *A. brevistyla* are outlined in the envirogram (**Figure 8**). Threats tend to be interrelated. For example, motor vehicles and livestock disturb soils and create favorable habitat for invasive non-native plant species, as well as disperse weed seed. Weeds may out-compete native plants and further damage habitat (Sheley and Petroff 1999). On National Forest System lands in Region 2, occurrences appear to be most vulnerable to recreational use of ATVs, dirt bikes, and off-road vehicles, and to invasive weeds encroaching on habitat. Livestock grazing, particularly trampling, is also a potential threat on National Forest System land. Snowmelt patterns that result in high instream flows may cause scouring along stream channels and could remove some *A. brevistyla* occurrences. Conversely, an extended drought could be even more detrimental. Although there seems to be little on a local level that can be done to avoid the consequences of global climate change, control of other pressures that stress the species may to some extent mitigate climatic impacts. Maintaining or increasing both the number and size of *A. brevistyla* occurrences can mitigate many threats and malentities.

Given that *Aquilegia brevistyla* occurrences in the contiguous 48 United States are restricted to the Black Hills and to Judith Basin County in Montana, they may be more vulnerable than those in the main northern range because they will experience similar environmental conditions and have a similar potential for pathogen infestation. Land use practices may also be more similar among occurrences within these two localized areas. Conversely, if environmental conditions and land use practices are optimum for *A. brevistyla* sustainability in either or both the Black Hills and Judith Basin County areas, these occurrences might be in a more secure position than those that are more widely distributed and experience many different threat conditions. Since many *A. brevistyla* occurrences in the Black Hills and Judith Basin County are found in close proximity to each other, a natural catastrophe is likely to affect multiple occurrences and a proportionally greater part of the total population. For example, a catastrophic fire aggravated by prolonged drought and high fuel loads has the potential to affect tens of thousands of acres (National Climatic Data Center 2002). Other examples include landslides, which are likely to affect all occurrences in their path, and occurrences distributed along a stream bank may all be subject to detrimental scouring during spring run-off.

Conservation Status of Aquilegia brevistyla in Region 2

In 2003, the USFS Region 2 designated *Aquilegia brevistyla* a sensitive species. Its status and perceived rarity prompted targeted surveys for the taxon between 2001 and 2005 on the Black Hills National Forest. These surveys recorded more than 90 occurrences or suboccurrences of *A. brevistyla*. In light of the results of these surveys, the USFS re-evaluated the status of *A. brevistyla* (Black Hills National Forest Evaluation Team 2004) and withdrew its sensitive species designation. *Aquilegia brevistyla* is currently considered to be secure in the Black Hills National Forest (Black Hills National Forest Evaluation Team 2004, Kratz 2005).

Management considerations for *Aquilegia brevistyla* conservation are outlined in the Black Hills Draft Environmental Impact Statement (USDA Forest Service 2004a). *Aquilegia brevistyla* was considered for Management Indicator Species (MIS) status by the Black Hills National Forest (Allen et al. 2004). The Forest Service Manual (1991) defines Management Indicator Species (MIS) as "…plant and animal species, communities, or special habitats selected for emphasis in planning, and which are monitored during forest plan implementation in order to assess the effects of management activities on their populations and the populations of other species with similar habitat needs which they may represent." The National Forest System Land and Resource Management Planning rule (47 FR 43037, September 30, 1982) requires that MIS be selected as part of the forest plan to estimate the effects of planning alternatives on fish and wildlife populations. *Aquilegia brevistyla* was not found to be an appropriate MIS because of its narrow habitat associations (Allen et al. 2004). However, rejection as a MIS did not suggest lack of management concerns for *A. brevistyla*. Rather, it was concluded that *A. brevistyla*'s management would be best addressed by mechanisms other than MIS designation (Allen et al. 2004).

An *Aquilegia brevistyla* occurrence reported in 1924 on the Shoshone National Forest has not been relocated (Fertig 1998, Wyoming Natural Diversity Database 2005). Fertig (2001) suggested that the specimen on which the record was based might be a hybrid individual involving *A. flavescens*, *A. formosa*, or *A. brevistyla*. This specimen was collected from the Lodgepole Creek/Crandall Creek area that currently has private in-holdings, so the occurrence may have been

on private land that is now inaccessible for survey. The area is managed for recreation, but many of the trails, including those down Crandall Creek and Lodgepole Creek, are closed to motorized trail vehicles. There have been no management plans or targeted surveys for *A. brevistyla* on the Shoshone National Forest.

Management of Aquilegia brevistyla in Region 2

Implications and potential conservation elements

Definitive and correct identification of a taxon is obviously of central importance to its conservation. This issue is particularly relevant to *Aquilegia brevistyla*, which has often been confused with other species. When assessing the value of the Black Hills occurrences, it is important to consider that disjunct occurrences of *A. brevistyla* in the contiguous United States may be important in maintaining the species' overall genetic diversity. Genes may become fixed through a process of local adaptation in small, isolated populations of *Aquilegia* species, with the consequence that there may be genetic variation among geographically separated populations.

Presently it is not known if *Aquilegia brevistyla* exhibits temporal fluctuations in abundance. At the turn of the twentieth century, *A. brevistyla* was observed consistently, but it was never reported to be abundant in the Black Hills. The reason *A. brevistyla* is abundant in the Black Hills at the present time is not known. The longevity of each individual or of any one occurrence is unknown, and the life history of *A. brevistyla* has not been studied. Many other *Aquilegia* species are short-lived perennials but have relatively long-lived occurrences in a given locale. It is possible that *A. brevistyla* occurrences fluctuate widely in range and size. As described in the Treatment of Uncertainty section, systematic observations of plant occurrences made over a long period may result in different conclusions than observations made over only a few consecutive years. For taxa where there are rare events with high levels of germination and recruitment against a background of low recruitment and mortality levels, a short-term study would have either missed these events or, if encountered, arrived at the erroneous conclusion that a high level of germination and recruitment is typical for the taxon (Coles 2003).

Elasticity analysis of individuals in an *Aquilegia chrysantha* population suggested that the persistence of medium-sized adults is important to population sustainability (see Demography section). If this stage of the life cycle is similarly important to *A. brevistyla*, disturbance from any source that results in loss of adult plants is significant, especially in small populations. If mature plants are killed and seed is dispersed only short distances, the local seed bank is likely to have a role in maintaining viable occurrences. Accelerated and/or increased soil erosion that often accompanies direct disturbance will negatively impact a soil seed bank. Although some *A. brevistyla* plants have been found near trails and road cuts, there is no indication that disturbance is a significant factor in *A. brevistyla*'s life cycle. The current plants at such sites may even be remnants of occurrences that were there prior to the disturbance.

Management practices may also contribute to the apparent variations in abundance of *Aquilegia brevistyla*, which may be sensitive to land management practices in ways that are not currently understood. For example, it is known that sheep grazing was most intense in the Black Hills National Forest at the turn of the twentieth century but has been discontinued since then. It is also known that *Aquilegia* species have been severely affected by sheep grazing in other areas (USDA Forest Service 1988, Bryce Canyon National Park undated). These facts suggest that changes in sheep grazing intensity may have contributed to the present high abundance of *A. brevistyla* in the Black Hills and that the species is recovering to pre-grazing levels. Such speculation cannot be proved since there are inadequate early records.

The extent to which habitat modification affects *Aquilegia brevistyla* occurrence size or survival cannot be determined from the available information. Euro-American settlement in the Black Hills has been widespread since the 1880's, and it is difficult to infer pre-settlement forest conditions from the current situation (Marriott et al. 1999). Substantial logging and timber harvest had already occurred by the time the first inventory for forest resources was conducted in the 1890's (Marriott et al. 1999). Although *A. brevistyla* grows in areas that experience frequent disturbance, such as stream banks and gravel stream channels, the majority of records indicate that it is part of a late-successional community type that experiences disturbance infrequently. Even low-intensity fires are not frequent in mesic *Picea glauca* forest ecosystems (Marriott et al. 1999).

Assessing the stability and potential security of a taxon without having records of its historic distribution and abundance is subject to error because the persistence

of a taxon *per se* is not proof that it has been unaffected by an activity or event. A decrease in reproductive output, a shift from sexual reproduction to vegetative reproduction, and/or a change in the belowground population size are all potential reactions that influence the future of a taxon, but are not considered by a simple observation of persistence.

The vulnerability of *Aquilegia brevistyla* occurrences in the Black Hills depends upon their location. Since *A. brevistyla* was added to the Region 2 sensitive species list, no timber sales have been planned in occupied *Picea glauca* habitat on the Hells Canyon Ranger District on the Black Hills National Forest (Buckert personal communication 2005). Many of the *A. brevistyla* occurrences in *P. glauca* forests are on steep slopes, which are among the low priority target areas for USFS management activities such as logging and livestock grazing (Burkhart personal communication 2005). In addition, these occurrences are unlikely to be directly impacted by most recreation activities. In contrast, several *A. brevistyla* occurrences (e.g. Black Fox Bog SD 22 and 23 and Elk Creek SD 56 in **Table 3**) are in areas that were described as "Ecologically-Vulnerable" during a project designed to inventory fragile habitats in the Black Hills National Forest (Paterson 2004). One of the principal purposes of this inventory was to identify areas that need protection from anthropogenic threats such as ATV recreation (Norbeck Society 2005). Such inventories are valuable since they focus on areas that need special management attention.

Pollinators may be essential for the reproduction and retention of genetic diversity by *Aquilegia brevistyla*. Management of the native vegetation, invasive species, and methods in dealing with insect pests may have profound effects on pollinator species (Bond 1995). Pesticide applications may need to be reviewed to ensure that the chemicals used to control species such as the bark beetle (*Ips* spp. and *Dendroctonus* spp.) do not impact the specific pollinators of *A. brevistyla*.

Tools and practices

Inventory and monitoring are important management tools for all plant taxa since they provide the only means of quantitatively determining their status. Representative *Aquilegia brevistyla* specimens need to be collected from each site, and it is essential that these specimens be carefully mounted, identified, and deposited at herbaria accessible to the public. Excellent community classification surveys have been recently conducted in the Black Hills (Marriott et al. 1999, Marriott and Faber-Langendoen 2000a, Marriott and Faber-Langendoen 2000b). This standardized classification system needs to be utilized when describing the habitat of *A. brevistyla* in order to clarify habitat requirements and to permit comparisons among occurrences.

Species inventory

Recent targeted surveys for *Aquilegia brevistyla* in the Black Hills National Forest have been very fruitful. A summary of the occurrences in South Dakota and Wyoming appears in **Table 3**. Most important in inventory surveys is an appreciation for the potential misidentification of vegetative plants. In Montana, vegetative specimens of *A. flavescens* have been mistaken in the field for *A. brevistyla* (Roe 1992). *Aquilegia flavescens* does not occur in the Black Hills, but *A. canadensis* is found there (Dorn 1977). *Aquilegia canadensis* is morphologically quite variable, and specimens have been documented as being confused with *A. brevistyla* (Whittemore 1997; see Description section). Field studies and surveys should be conducted when plants are flowering or have fruit. Fruit are useful in identifying *A. brevistyla* because the follicle beak length is a distinguishing characteristic.

The field survey forms for plant species of concern used by the Black Hills National Forest request data that is appropriate for inventory purposes. Additional examples of field data collection forms appear on the Wyoming Natural Diversity Database and Montana Natural Heritage Program websites (addresses in the **References** section). The number of stems, the area they occupy, and associated habitat descriptions are important information for comparing occurrences. The easiest way to describe occurrences scattered across a broad area may be to count patches, make note of their extent, and estimate or count the numbers of stems within patches. When reporting the data, it is important to state clearly whether the counting unit is stems or individual plants. Recording reproductive stages (i.e., flowering plant, rosette, seedling) is valuable for assessing the potential sustainability of an occurrence. Distinguishing between plants that have reproduced during the current growing season, that are vegetative, that are past mature fruit production, or that have had their reproductive organs removed, is also important when evaluating the potential sustainability of an occurrence.

During a species inventory, habitat characteristics of the occurrence also need to be recorded, ideally using the classification system developed specifically for the Black Hills (Marriott et al. 1999, Marriott and Faber-

Langendoen 2000a, 2000b). Habitat characteristics are especially useful because they provide a context for comparing the occurrence with other occurrences or the same occurrence in future years. Overstory canopy and shade from cliffs may be particularly important facets of *Aquilegia brevistyla*'s ecology. A spherical densiometer is useful for measuring canopy cover accurately because it tends to pick up traces of canopy or geological formations that are missed by subjective assessment. The time of day that plants receive direct sunshine may also be important in explaining the patchy distribution of *A. brevistyla*. Other important habitat features include the actual and relative wetness of the site, the associated species, especially bryophytes, and the presence of non-native species. Current land use designations and evidence of land use activities such as hiking, biking, or livestock grazing need to be noted. Records of disturbance are valuable for placing *A. brevistyla* plants in their ecological context as well as for assessing threats to an occurrence. Examples of disturbance elements include rodent burrows, anthills, and soil erosion channels, as well as elements derived from anthropogenic causes.

A sketch of the site indicating the distribution of plants is also helpful for future reference. Location coordinates of each occurrence, and sometimes each sub-occurrence, are customarily acquired using global positioning system (GPS) technology. Delineating the perimeter of each area containing plants using GPS and transferring the data on to topographic maps may be a practical way to record the distribution of *Aquilegia brevistyla*.

The existing *Aquilegia brevistyla* survey data for the Black Hills need to be analyzed to determine whether the methods used and the information collected are adequate or if changes need to be made in future surveys. Ongoing inventories benefit from periodic analyses and summaries of data. When reporting survey results, it is particularly important to document areas that have been surveyed but where no target plants were found. Negative survey information is frequently under-reported, resulting in an incomplete understanding of the species' frequency and distribution within a region. Surveying additional areas in the Central Crystalline Core region of the Black Hills would be particularly helpful in determining the habitat restrictions of *A. brevistyla*. Other potentially rewarding areas for surveys are in the southern part of Black Hills National Forest, e.g. sections in and around the Jewel Cave National Monument, where historic occurrences have been reported.

Habitat inventory

The habitat information available for *Aquilegia brevistyla* occurrences in Region 2 is insufficient to adequately characterize suitable habitat in the absence of plants. There have been no studies to relate the abundance or vigor of populations to specific habitat conditions, even to the level of coarse measures such as elevation. The patchy and sparse distribution pattern of *A. brevistyla* suggests that certain specific, and as yet largely unknown, microclimate and edaphic conditions are needed to support plants (see Community Ecology section). Available habitat descriptions suggest that, within the broad restrictions of geology and the eco-climate zones in which it exists, *A. brevistyla* can grow in a variety of moist to semi-moist habitats (see Habitat section).

Population monitoring

No demographic or monitoring studies have been conducted on *Aquilegia brevistyla*, and no permanent monitoring plots have been established in Region 2. Occurrence records on the Black Hills National Forest have been collected over several decades, but the amount of information gathered at each occurrence differs, and information on abundance has only recently been reported (**Table 3**). Older records are based on herbarium collections and it is only within in the past 10 years that targeted surveys for *A. brevistyla* have been conducted on the National Forest. In-depth demographic studies of *A. brevistyla* occurrences would entail some level of destructive sampling (in depth studies may need to excavate plants to determine the number of stems per individual, etc.) and are unlikely to be appropriate for the small, isolated occurrences of the taxon. On the other hand, monitoring would be valuable, and a study of the population dynamics may be useful in developing appropriate management practices.

The monitoring protocol needs to be chosen according to the goals of the study. Elzinga et al. (1998, 2001) suggested alternative procedures and appropriate statistical methods. Close consultation with a statistician is invaluable before collecting quantitative data. Variable occurrence sizes and distributions of plants within the occurrences need to be considered prior to initiating a monitoring study. Permanent transects or plots may be an appropriate way to study long-term trends. Lesica (1987) has discussed a technique for monitoring perennial plant species using permanent belt transects. Elzinga et al. (1998) and Goldsmith (1991) have discussed using rectangular quadrant

frames along transect lines to effectively monitor the "clumped-gradient nature" of occurrences. If *Aquilegia brevistyla* patches prove to be spatially dynamic across the landscape, then monitoring permanent plots might lead to problems associated with spatial auto-correlation (Goldsmith 1991). If the size of the plot is too small or if the establishment of new plots is not part of the original scheme, then when plants die and no replacement occurs within the plot, it is impossible to know the significance of the change without studying a very large number of similar plots. Given that seeds likely disperse a short distance and that adult plants may be relatively long-lived, it is expected that patches of *A. brevistyla* plants would be persistent. However, this has not been confirmed. There may be serial colonizations and extirpations of patches. Therefore, until the population dynamics are known for this species, it is important to monitor the areas between sub-occurrences to ensure that any shifts in stands within an occurrence are recognized.

It is not known if *Aquilegia brevistyla* exhibits prolonged dormancy, but this is a facet of its biology that needs to be considered. Lesica and Steele (1994) discussed the monitoring implications of prolonged dormancy in vascular plants. They concluded that for plants with prolonged dormancy, population estimates based on random sampling methods will often underestimate density. They also suggested that demographic monitoring studies of species with prolonged dormancy would require longer periods of time to obtain useful information. In order to monitor changes in population density with a reduced risk of bias, establishing permanent monitoring plots with repeated measure analysis may be most effective (Lesica and Steele 1994).

Information on size or size class is more effective than attempting to describe the age of individual plants in a monitoring scheme (see Demography section). Strand (1997) and Stubben and Milligan (2001) used size classes to develop a stage projection model of *Aquilegia chrysantha* after the method of Lefkovitch (1965). This would be an appropriate course of action when studying *A. brevistyla*. Monitoring studies where individuals are tracked over several years would provide valuable information on the longevity of individuals and the persistence of occurrences. Monitoring protocols need to include a measure of the abundance of noxious weeds so that appropriate action may be taken to control them.

Establishing photo points can be very helpful in describing site conditions and recording coarse-scale vegetation changes over time. This technique is increasingly used to supplement monitoring records. However, photographic documentation is not an effective replacement for written observations and quantitative monitoring procedures. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hard copies since in 50 years time the technology to read current media may no longer be available.

Habitat monitoring

Habitat monitoring in the absence of *Aquilegia brevistyla* plants is not possible since there is no established concept of suitable habitat. Habitat monitoring in the presence of plant occurrences is customarily a part of population monitoring protocols. Descriptions of habitat are valuable during population monitoring activities in order to link environmental conditions with changes in plant abundance over the long-term. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities, for example hiking, biking, or livestock grazing, are important elements of monitoring data.

Population or habitat management approaches

Baseline inventory data were collected recently for *Aquilegia brevistyla* in the Black Hills National Forest. Completing a comprehensive inventory of a taxon assists in evaluating its vulnerability to local extirpations. However, no monitoring programs have been established for *A. brevistyla* in Region 2. Long-term monitoring of occurrences is the only way to determine trends in a taxon's population size and range. Monitoring occurrences in areas before and after new management practices have been implemented is an ideal way to evaluate the effects of the changes.

Management practices that may be beneficial to *Aquilegia brevistyla* habitat that have been generally implemented within the Black Hills National Forest include restricting recreational vehicle traffic in wetland areas and routing hikers to designated trails. Paterson (2004) made several recommendations for conservation of "Ecologically-Sensitive Areas," some of which include *A. brevistyla* habitat, in the Black Hills National Forest. His recommendations included erecting fences, establishing barriers to ATVs, and/or posting signs indicating that the areas are closed. The effectiveness of signs may depend upon the site and the site users. Signs

were not successful in preventing damage from ATVs to the Black Fox Sphagnum Bog on the Black Hills National Forest (Norbeck Society 2005).

Formally designating a taxon as a sensitive species in Region 2 is a useful conservation tool for at least two reasons. Sensitive species designation requires that the taxon be reviewed during management planning. It also raises awareness of the species to botanists and ecologists outside the USFS and may stimulate interest in reporting occurrences and including the taxon in research projects. Due to *Aquilegia brevistyla* being designated a sensitive species in 2003, field surveys for the species on the Black Hills National Forest were made in 2003 and 2004. These surveys generated large volumes of data that still need to be analyzed in detail. The Black Hills National Forest botany staff intends to record the presence of *A. brevistyla* if encountered incidentally to other survey projects (Burkhart et al. personal communication 2006). However, without sensitive species designation, *A. brevistyla* may be overlooked because its current management is subject to the individual land manager's personal knowledge of the species, and the continuity of a management strategy is not assured should the land manager leave the area.

Aquilegia brevistyla seed does not appear to have been saved in a seed bank. Banked seed could be important if restoration is necessary in the future. However, seed banking may have limited value for restoring a taxon whose ecology is not well understood. If microhabitat requirements are not known, the conditions to maintain an occurrence may not be met even if germination and seedling establishment are achieved. Therefore, re-establishing occurrences that have been extirpated may be a very difficult task.

Information Needs

There is little information on the population structure of *Aquilegia brevistyla* or the persistence of either individuals or populations. Periodic monitoring of existing sites and further inventory would clarify that situation. Monitoring is essential in order to understand the implications of existing and new management practices. The consequences of a change in management practices can be evaluated objectively if baseline data are available and if a monitoring program is installed that is specifically designed to measure effects.

The factors that limit *Aquilegia brevistyla* abundance and contribute to annual variations in occurrence size are not known. Habitat requirements, including associations with non-vascular species, need to be more rigorously defined. For example, it is unknown if the association between bryophytes and *A. brevistyla* is purely based on a shared habitat niche or whether there are eco-physiological (e.g., maintaining positive soil water balance), or biological (e.g., a reciprocal soil microbial community) interactions. More information is needed on the life history and population dynamics of *A. brevistyla*. The extent to which *A. brevistyla* propagates vegetatively needs to be clarified. The rate of colonization, potential for seed dispersal, and seed bank dynamics as well as the availability of appropriate habitat can influence how populations recover after significant disturbance. Considering the potential vulnerability to genetic loss, research needs to be carried out before artificially establishing new occurrences or including *A. brevistyla* in vegetation seed mixes. The potential impact of non-native invasive plants is also unknown. More information on how *A. brevistyla* responds to competition with non-native species is important because invasive alien species are a substantial problem in many parts of its range.

The prioritization of information needs depends upon management goals and may be influenced by changing circumstances. At the present time, the primary information needs for *Aquilegia brevistyla* include:

- the impacts of potential threats on this species and its habitat need to be determined in order to facilitate proactive steps towards threat mitigation
- the temporal stability of occurrences needs to be determined by monitoring known sites
- the habitat requirements of this species need to be rigorously defined so that reasons for colonization and occurrence size restrictions are known
- a complete understanding of the current range and abundance of *A. brevistyla* is needed; this can be achieved by further inventory in regions that have not been surveyed within the last decade
- the reproductive biology, the potential for vegetative propagation, and the population dynamics of this species need to be clarified.

DEFINITIONS

Allele – form of a given gene (Allaby 1992).

Allelopathy – "the release into the environment by an organism of a chemical substance that acts as a germination or growth inhibitor of another organism" (Allaby 1992).

Apparently suitable habitat – "surveyed or unsurveyed areas not known to be occupied by an element, but which appear capable (under natural conditions) of supporting viable individuals of that element, based on one or more observed or mapped factors (soils, geology, hydrology, vegetation, topography, aspect, elevation, etc.) known to delimit or predict other occurrences (current or historical) of the same element" (NatureServe 2004a).

Autogamous or Autogamy – self-fertilized, self-fertilization.

Broad-leaved species – most typically used in weed science or agronomy to describe herbaceous dicots, alternatively known as forbs.

Caudex – the perennial region between the base of the stem and the top of the roots that is slowly elongating and commonly branched.

Contiguous United States – the United States of America is divided into three distinct sections:

(1) The "continental United States," also known as "the Lower 48," and more accurately termed the conterminous, coterminous, or contiguous United States.

(2) Alaska, which is physically connected only to Canada

(3) The archipelago of Hawaii, in the central Pacific Ocean.

Cytogenetic – a scientific discipline that combines cytology (the study of the structure, function, and life history of the cell) with genetics (the study of heredity), and usually involves microscopic studies of chromosomes (Allaby 19992).

Disjunct – in the context of this report, "disjunct" refers to an occurrence or population of a species, widely separated geographically from other occurrences or populations of the same species.

Edaphic – of the soil, or influenced by the soil (Allaby 1992).

Follicle – a dry fruit derived from a single carpel (the female reproductive organ that includes an ovary), which dehisces along one side only (Allaby 1992).

Forb – herbaceous dicots.

Geitonogamy – fertilization of flowers by pollen from other flowers on the same plant.

Geophyte – a land plant that survives an unfavorable period by means of an underground storage-organ (Raunkiaer 1934, Allaby 1992).

Heterozygote – a diploid or polyploid individual that has different alleles at least one locus.

Holocene – an epoch of the Quaternary period, from the end of the Pleistocene to the present time (Bates and Jackson 1976).

Homozygote – an individual having the same alleles at one or more loci.

Inbreeding depression – this refers to the condition when a plant experiences a lack of fitness due to weakness in some aspect of its physiology. For example, its germination, its competitive ability, its over-wintering ability, or its reproductive effort may be compromised in some way. Inbreeding depression may be due to deleterious recessive or partially recessive alleles, which are usually masked at heterozygous loci by dominant alleles, becoming fully expressed in homozygotes or, alternatively, alleles may interact in an overdominant manner, such that the fitness of either type of homozygote is lower than that of heterozygotes (Dudash and Carr 1998).

Isotype – a duplicate specimen of the holotype collected at the same place and time as the holotype.

Iteroparous – experiencing several reproductive periods, usually one each year for a number of years, before it dies.

Intrageneric – within the same genus; among members of the same genus.

Lepidoptera – butterflies and moths; insects characterized by having two pairs of large wings, both wings and body covered with scales, and its larva being a caterpillar (Abercrombie et al. 1973).

Linear riparian systems – "systems dominated by water-current dispersal in a linear zone generally <1 km wide (riparian corridors, shores, and similar narrow systems), including those with dispersal by occasional events (major floods, storm waves, etc.) with significant potential to occur during the next 25 years. …. EO [occurrence] features are assumed to share linear flow if they are aligned in a reasonable flow direction along a river, stream, shore, etc., unless contrary data exist. This is usually not the case with upstream EO features on different tributaries or with EO features on opposite shores of rivers >1 km wide; however, such features may be indirectly connected if they each share flow with a common downstream EO feature" (NatureServe 2004b).

Loci – plural of locus; specific places on a chromosome where genes are located (Allaby 1992).

Mesic – sites or habitats characterized by intermediate moisture conditions; neither decidedly wet (hygric) nor decidedly dry (xeric).

Mesic soils – those soils where water is removed fairly slowly in relation to supply and may remain moist for a significant, if sometimes short, period of the year; available soil moisture comes from precipitation (rain and snow) in moderate- to fine-textured soils and limited seepage in coarse- textured soils (Klinkenberg 2004).

Metapopulation – a composite population; a population of populations in discrete patches that are linked by migration and extinction.

Montane Zone – region of relatively moist cool upland slopes below timberline and characterized by the presence of large evergreen trees as a dominant life form (Webster's Third New International Dictionary of the English Language, 1971).

Mycorrhiza, Mycorrhizal association – a close physical association between a fungus and the roots of a plant, from which both fungus and plant appear to benefit; a mycorrhizal root takes up nutrients more efficiently than does an uninfected root (Allaby 1992).

Outbreeding depression – a reduction in fitness that results from mating between unrelated or distantly related individuals; it may result from loss of local adaptation or from the breakup of gene combinations favored by natural selection; in the latter case, the effects of outbreeding depression are thought to depend on epistasis, or interactions between different loci (Lynch 1991).

Persistently unsuitable habitat – "surveyed or unsurveyed areas that, under natural conditions, are virtually certain to remain incapable of supporting viable individuals of an element during the next 25 years or more. Such areas are neither apparently suitable habitat nor parts of a dynamic landscape mosaic that includes the element (see definitions below). The potential for rare or highly irregular events (such as tornadoes, unusual hurricanes, earthquakes, 300-year floods, rare fires, or catastrophic volcanism) may be ignored. Similarly, incremental effects of long-term phenomena (such as slow erosion or deposition, climate change, or sea-level rise) may usually be ignored on the timescale of interest here; over longer times, almost everything changes" (NatureServe 2004a).

pH – a measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality, lower numbers indicate increasing acidity, and higher numbers indicate increasing alkalinity; each unit of change represents a tenfold change in acidity or alkalinity and is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of the solution.

Pleistocene – also referred to as the Ice Age; an epoch of the Quaternary period, beginning two to three million years ago and lasted until the beginning of the Holocene 8,000 years ago. (Bates and Jackson 1976).

Protandrous – the anthers (male organs) mature before the carpels (female organs).

Ranks – NatureServe and the Heritage Programs Ranking system. G5 indicates that *Aquilegia brevistyla* is "Secure – Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

S1 – Critically Imperiled. Critically imperiled in the state or province [in this context] because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).

S2 – Imperiled. Imperiled in the state or province [in this context] because of rarity or because of some factor(s) making it very vulnerable to extirpation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).

S3 – Vulnerable. Vulnerable in the state or province [in this context] either because it is rare and uncommon, or is found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.

S4 – Apparently Secure. Uncommon but not rare, and usually widespread in the state or province [in this context]. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.

S5 – Secure. Common, widespread, and abundant in the state or province [in this context]. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

For more information on conservation status rank see http://www.natureserve.org/explorer/granks.htm.

Rhizomatous – possessing rhizomes.

Rhizome – a horizontally creeping underground stem that bears roots and leaves and usually persists from season to season (Allaby 1992).

Seep – a spot where water, or another fluid, trickles out of the ground to form a pool (Guralnik 1982).

Seepage – in general, the flow of water through soil pores; in the disciplines of soil mechanics and hydrology there are technical definitions for different types of seepage, and the precise use of the term depends upon context (Langbein and Iseri 1995).

Stochasticity – randomness, arising from chance; Frankel et al. (1995) replaced the word "stochasticity" by "uncertainty" to describe random variation in different elements of population viability.

Style – in flowering plants, an extension of a carpel that supports the stigma

Sympatric – the occurrence of two species together in the same area (Allaby 1992).

Toe slope – the break in slope at the foot of a bank where the bank meets the bed.

Triternate – three times ternate where ternate is "arranged in three's;" ternate with the three main divisions once and once-again ternate (Harrington and Durrell 1986).

Type specimen – an individual plant chosen by taxonomists to serve as a basis for naming and describing a new species or variety (Allaby 1992).

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